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## THE DEVELOPMENT AND FUNCTION OF THE CELL PLATE IN HIGHER PLANTS.

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(WITH PLATES VIII AND IX)

### Historical.

ASIDE from the work of Strasburger there have been very few investigations reported that have treated fully the subject of the cell plate and its history in the vegetable cell. So far as I know, the term cell plate was first used in its present sense by Strasburger in the first edition of *Zellbildung und Zelltheilung*. It was here that he made the statement that the beginning of the cell plate is to be found in swellings of the connecting spindle fibers. The subject was more fully discussed in the third edition of the above work, and I shall refer to that in greater detail below.

In 1878 Treub published his classic researches on the rôle of the nucleus in cell division,[1] in which he describes the process of cell plate and cell wall formation in the living cells of the proembryo of *Orchis latifolia* and the ovules of *Epipactis palustris*. By keeping the tissues in a 1.25 per cent. solution of $KNO_3$ he was able to make an extended study of the above processes. The first indication of the formation of a cell plate is a collection of granules across the equatorial region of the spindle, which move into place from various directions in the cytoplasm. They

[1] Quelques recherches sur le rôle du noyau dans la division des cellules végétales. Amsterdam, 1878.

have, therefore, no connection with the spindle fibers. After reaching the equator the granules fuse into a continuous layer across the central spindle. The growth of the cell plate occurs by the addition of new material either all around, if the spindle is in the middle part of the cell, or on the free sides, if the spindle is near one side of the cell so that the cell plate has reached the mother cell wall on that side where it is first formed, *i. e.*, the whole nuclear figure moves across the cell, building the cell plate as it goes. By plasmolyzing the cell by the addition of more $KNO_3$ Treub was able to demonstrate that the new cell wall is laid down between the split halves of the cell plate.

In the third edition of *Zellbildung und Zelltheilung* Strasburger gave the most comprehensive account of the cell plate that has ever appeared. One of the important facts that he describes in this work is the apparent increase in the number of connecting fibers prior to the formation of the cell plate (*op. cit.*, p. 341). There are a few spindle fibers extending through the cell plasma between the receding groups of daughter chromosomes. These fibers can be distinguished from the surrounding cell plasma by their filar form. Their number is increased by the addition of new fibers differentiated out of the cytoplasm. The new fibers are identical, in so far as their staining qualities and form are concerned, with the original fibers. This apparent identity is evidence for the cytoplasmic origin of spindle fibers. The hypothesis is strengthened by the process of division of those pollen mother cells which divide simultaneously, where new connecting fibers are formed from the cytoplasm after the two daughter nuclei of the first division have again divided, and the original connecting fibers, with the cell plate formed in them, have disappeared. The permanent cell plate is then formed in these new fibers (*op. cit.*, p. 345). In the spore mother cells of Anthoceros and the macrospore mother cells of Isoetes, the spindle fibers in which the cell plates are formed connect the four daughter plasma masses or chromatophores, instead of the nuclei. Davis[2] has recently reinvestigated the division of the

[2] The spore mother cell of Anthoceros. BOT. GAZ. **28**: 89. 1899.

spore mother cell of Anthoceros and has found that the cell plate is formed upon cytoplasmic strands (not spindle fibers) uniting the four chromatophores. A portion of this cell plate becomes converted into a cell wall.

In endosperm formation there are a great number of nuclear divisions that are not followed directly by divisions of the cell. The spindle in each case disappears after each nucleus divides.[3] When the above process has continued until there are a great many nuclei lying free in the protoplasm, new fibers are formed connecting each nucleus with all of its immediate neighbors. In these fibers the cell plates are built in the usual manner. In a later work[4] these new fibers were described as growing out of a hyaline plasma mass around each nucleus.

On the nature of the cell plate elements, *i. e.*, the granules which form the cell plate, we have an interesting statement.[5] The cell plate is formed of small granules whose chemical nature is hard to determine. That they may be starch is indicated by the fact that they take in some cases a blue stain when treated with iodine. In most cases, however, they are not thus stained. They may be a substance between starch and cellulose. This hypothesis is rendered more probable by the fact that the cell plate elements are apparently used directly to form a cellulose wall instead of being converted into a protoplasmic layer which splits and excretes a cellulose layer between the halves.

In the pollen mother cells of the Cycadaceæ, Juranyi[6] described a process of cell wall formation by the conjunction of a cellulose ring, growing in from the mother cell wall and a new wall formed in the connecting spindle.

In 1882 Strasburger modified his previous view as to the origin and chemical nature of the cell plate elements.[7] In this paper he holds that with the aid of suitable stains it can be shown

[3] STRASBURGER, *op. cit.*, p. 345.

[4] Ueber Kern- und Zelltheilung im Pflanzenreich. Hist. Beitr. 1. 1888.

[5] Zellbildung und Zelltheilung, 3. Aufl., 342.

[6] Mittheilungen über Structur u. Bildung des Zellkernes. Ref. in Botan. Centralb. 12:213. 1882.

[7] Ueber den Bau u. d. Wachsthum der Zellhäute 172. Jena, 1882.

that the granules of the cell plate react as albumen. As to the origin of these granules it was observed that they are not added from the surrounding protoplasm but are within the fibers themselves. The fibers appear as if made up of small granules. These granules are really contained in the fibers as if in tubes, and they collect at the equator, forming apparent equatorial swellings of the fibers, *i. e.*, the cell plate elements. The cell plate elements, after growing by the addition of new granules, finally fuse into a continuous plate.

In 1887 Went[8] showed that connecting fibers and other spindle fibers are identical, and that the former apparently increase in number before the cell plate appears. He was not able, however, to account for the origin of the new fibers. Prior to the formation of the cell plate, Went observed a stained substance between the fibers of the connecting spindle next to the daughter nuclei, leaving thus a clear zone in the equator of the spindle. This stained substance was thought to be nucleolar matter dissolved in the nuclear sap. In the subsequent stages these two darker zones move to the equator where the cell plate is built. Its origin Went did not see, but he showed that its growth is peripheral, as had been well established by previous observers. Went, however, observed for the first time that the connecting fibers disappear in the center of the spindle during the growth of the cell plate, so that the peripheral fibers form a ring connected with the growing region of the plate.

Opposed to the view of Strasburger as to the cytoplasmic origin of the cell plate by fusion of swellings of the connecting fibers, was that of Zacharias,[9] who contended that the spindle is of nuclear and the cell plate of cytoplasmic origin, thus following Treub's theory of the origin of the cell plate from free granules. The cell plate is formed by the entrance of substance from the surrounding protoplasm into the equatorial region of the central spindle, which is a portion of the dividing nucleus

[8] Beobachtungen über Kern u. Zelltheilung. Ber. d. deutschen botan. Ges. 247. 1887.

[9] Ueber Kern u. Zelltheilung. Botanische Zeitung **46**: 56. 1888.

(*Mutterkernrest*) having a homogeneous structure and hyaline appearance. In a later contribution he ascribed the filar structure of the central spindle to the effect of reagents, especially absolute alcohol.

In connection with his researches on fertilization Guignard[10] observed that the number of connecting fibers is equal to the number of chromosomes, and that these fibers are formed by the fusion of smaller primary fibers.

Later Strasburger[11] confirmed the views of Went as to the staining properties of the nuclear sap and the relation of the substance in it to cell plate formation. He also described the formation of a temporary plasma membrane about the connecting spindle, and suggested that the change in the form of the nuclear figure, *i. e.*, the bulging out of the connecting fibers, is due to the osmotic action of the nuclear sap held within this membrane.

In 1893 Wildeman[12] described in the rhizoids of mosses a process of division wall formation in which the spindle is first arranged so that its long axis is parallel to the long axis of the cell. Previous to the formation of the cell plate, it is changed to an oblique direction, but the young cell wall is so curved as to become attached perpendicularly to the mother cell wall in accordance with Sachs's law of "orthogonal trajectories."

In 1895 Strasburger[13] claimed new evidence for the identity in character of connecting fibers and other spindle fibers in the fact that their staining qualities were the same. In preparations stained with the triple stain of Flemming he observed that, while the cell plate is being formed, the connecting fibers go through all gradations from violet (the color of spindle fibers) to brown (the cytoplasmic color), thus confirming his earlier opinion as to the cytoplasmic nature of spindle fibers. From the fact that

[10] Nouvelles études sur la fecondation. Ann. des Sci. Nat. Bot. VII. **14** : 163.

[11] Histologische Beiträge 1 : 162 *et seq.*

[12] Études sur l'attache des cloisons cellulaires. Mémoires couronnés et mémories d. sav. etr. p. p. l'Acad. Roy. d. Sci. de Belgique **53** : 19. 1893.

[13] Karyokinetische Probleme. Jahrb. f. wiss. Bot. **28** : 193. 1895.

shortly before the cell plate is formed "extra-nuclear nucleoli" appear in large numbers in the equatorial region of the spindle, and that by the time the cell plate is complete these have disappeared, he argues that the nucleolus takes part in building the cell plate.

In the pollen mother cells of *Lilium Martagon*, Farmer[14] found that the protoplasm of the connecting spindle on each side of the newly formed cell plate is relatively transparent.

The series of contributions which appeared from the Bonn laboratory in 1897 presented several important facts in regard to the formation of the cell plate. Mottier[15] found in the pollen mother cells of the lily that the cell plate is split into plasma membranes before the cell wall is laid down. In cells plasmolyzed in fixing, a complete plasma membrane was seen around each daughter cell, while no cellulose wall could be observed (*op. cit.*, p. 192). In the pollen mother cells of *Hemerocallis fulva*, Juel[16] found that after the first nuclear division the cell plate did not reach the mother wall but remained free in the cytoplasm until the second nuclear division occurred and new cell plates were formed at right angles to it. Then some of the fibers radiating from the daughter nuclei become attached to the old plate, and all the cell plates now continue their respective growths toward the mother cell wall. Debski[17] studied the division of the segment cells of Chara and observed that the long axis of the spindle is parallel to the shorter axis of the cell and further that the cell plate is not formed across the equator of the spindle but nearer one nucleus. In the formation of the ascospores in the asci of Erysiphe and Peziza, Harper[18] found

[14] Kerntheilung in Lilium Antheren, besonders in Bezug auf die Centrosomenfrage. Flora **83**: 167. 1895.

[15] Beiträge zur Kenntniss der Kerntheilung in den Pollenmutterzellen einiger Dikotylen u. Monokotylen. Jahrb. f. wiss. Bot. **30**: 169. 1897.

[16] Die Kerntheilungen in den Pollenmutterzellen von *Hemerocallis fulva*, und die bei denselben auftretenden Unregelmässigkeiten. Jahrb. f. wiss. Bot. **30**: 205. 1897.

[17] Beobachtungen über Kerntheilung bie *Chara fragilis*. Jahrb. f. wiss. Bot. **30**: 227. 1897.

[18] Kerntheilung und freie Zellbildung im Ascus. Jahrb. f. wiss. Bot. **30**: 249. 1897.

that the plasma membrane around each ascospore was formed by the growth and lateral fusion of the polar radiations, a process which is essentially similar to the formation of the cell plate in higher plants.

In the division by which the "beaks" are cut off from the gametes in Basidiobolus, a typical cell plate is formed, according to Fairchild,[19] from two rows of granules, whose origin was not discovered, in the equatorial region of the spindle. In some of the Sphacelariaceæ Swingle[20] confirmed the previous observations of Strasburger, that the cell plate is not formed in a connecting spindle, but arises in the cytoplasmic network. Swingle suggested, however, that its formation may be under the control of the nuclei by means of the kinoplasmic fibers which radiate from the poles, although there are not enough of such fibers actually to form it. An important point in this connection is the fact that if the daughter nuclei are of unequal size the cell plate is formed nearer the smaller nucleus, as Debski described for Chara. In the oogonium of Fucus, Strasburger[21] found a cell plate built of granules which he considers extra nuclear nucleoli arranged in the cytoplasm. The granules divide so as to form two layers out of which are formed continuous membranes. Discussing the subject more generally, Strasburger[22] places great emphasis upon the kinoplasmic nature of the cell plate He points out the fact that the formation of a cell plate by the fusion of swellings of the connecting fibers is analogous to the formation of the plasma membrane around the ascospores as described by Harper. In the case of the ascospores there is no doubt of a transformation of the substance of the fibers (polar radiations) into a plasma membrane. In the case of the cell plate, while it is equally evident that there is a transformation of

[19] Ueber Kerntheilung und Befruchtung bei *Basidiobolus ranarum* Eidam. Jahrb. f. wiss. Bot. **30**: 285. 1897.

[20] Zur Kenntniss der Kern- und Zelltheilung bei den Sphacelariaceen. Jahrb. f. wiss. Bot. **30**: 297. 1897.

[21] Kerntheilung und Befruchtung bei Fucus. Jahrb. f. wiss. Bot. **30**: 351. 1897.

[22] Ueber Cytoplasmastructuren im Kern- u. Zelltheilung. Jahrb. f. wiss. Bot. **30**: 375. 1897.

fiber substance into a lamella from which is derived the plasma membrane of the daughter cells, Strasburger was not then certain whether the cell plate forms simply the plasma membranes, or whether a part of it may be changed into a division wall (*op. cit.*, p. 38). In a subsequent contribution,[23] however, he made the statement that the cell plate forms a plasma membrane (*Hautschicht*), that it splits to form a plasma membrane for each daughter cell, and that the substance of the cellulose wall is excreted by these daughter plasma membranes and laid down as a wall between them.

Hof[24] has recently described in the division of vegetative cells what I take to be the same appearance as that described by Went and Strasburger, viz., the deeply stained portions of the spindle moving toward the equator and there taking part in the formation of the cell plate. He, however, describes the substance of these zones as granular rather than as material in solution in the nuclear sap. After the cell plate is complete the connecting fibers are entirely drawn in (*eingezogen*) and their place taken by alveolar cytoplasm. Just what Hof means by the drawing in of the connecting fibers is a question left unsettled in his description. They may be drawn into the nucleus or into the cell plate. His figures do not help at all in understanding his meaning in this instance.

Nemec[25] has recently described the same phenomena as to the formation of the cell plate in the growing root tips of *Allium Cepa*. He adds further that new connecting fibers make their appearance after these zones have reached the equator. The fact that these new fibers often seem to end free between the original fibers, Nemec considers as evidence for their origin from the stained substance now at the equator.

The observations of Strasburger as to the method of cell plate formation in the oogonium of Fucus were not wholly

[23] Zellhäute. Jahrb. f. wiss. Bot. **31**: 514. 1898.

[24] Histologische Studien am Vegetationspunkten. Bot. Centralb. **76**: 221. 1898.

[25] Ueber die karyokinetische Kerntheilung in der Wurzelspitze von *Allium Cepa*. Jahrb. f. wiss. Bot. **32**: 313. 1899.

confirmed by Farmer and Williams.[26] These investigators found that there is an accumulation of material, which they think is some form of a carbohydrate, in the neutral zone between the daughter nuclei of the future oospheres. There is, however, no trace of a preliminary cell plate. While spindle fibers were seen reaching from the poles to the equatorial region of the cell, no evidence was found that they take part formatively in the building of the division wall.

In an early paper Strasburger had pointed out the difference between the method of division of the cell body of animal cells and that of the higher plants, by stating that in the former the connecting spindle fibers take no part in the division of the cell body, but that the division is accomplished by the constriction of the plasma membrane; whereas in the latter these fibers are increased in number and take part in the division of the cell by forming a cell plate. This view Carnoy[27] attempted to overthrow in his work on the testicular cells of some arthropods, in which he claimed to have found a cell plate formed of two parts, a cytoplasmic part formed by thickenings appearing on the junctures of the cytoplasmic network, and a spindle part formed by swellings on the connecting spindle fibers. I have not been able to find that this work has been confirmed by subsequent investigators. The spindle portion (*plaque fusoriale*) of Carnoy is undoubtedly the midbody (*Zwischenkörper*) subsequently described by Flemming[28] and others as arising from granules in the equatorial region of the spindle, but not always as swellings of the spindle fibers. Notwithstanding the fact that it takes no part in the division of the cell body, Flemming was inclined to consider it the homologue of the cell plate in the higher plants. The midbody has received a great deal of attention from the zoologists, and various views have been held as to its significance and fate. The literature on the subject has been

[26] Contributions to our knowledge of the Fucaceæ. Philos. Trans. of the Roy. Soc. London B. **190**: 623.

[27] La cytodiérèse chez les arthopodes. La Cellule **1**: 375.

[28] Neue Beiträge zur Kenntniss der Zelle. Arch. für mikr. Anat. **38**: 690.

recently succinctly reviewed by Ballowitz,[29] so that I need not go over it here. Ballowitz finds that the midbody is formed by the fusion of swellings of the central spindle fibers. His observation differs from Flemming's in that the latter thought the granules were sometimes between the fibers. Ballowitz and Flemming agree that the midbody takes no part in the division of the cell, but may be seen between the two daughter cells after division is complete. In a very interesting paper by Kostanecki,[30] upon the relation of polar radiations to the division of the cell body, the view is developed that the division is effected by a cell plate built in the cytoplasm by means of two systems of polar radiations which connect the granular cell boundary with the centrosomes. During the metaphases the longer fibers from each centrosome, which cross each other in the equatorial region of the cell, contract and so change their points of attachments to the plasma membrane until they reach the equator. They now draw in toward the central spindle, pulling in with them a substance similar to that of the cell boundary, thus forming what the author calls an equatorial granular cell plate. The division of the cell depends primarily upon the differentiation of the cell plate into two layers under the influence of the opposite system of polar radiations. Kostanecki states further that he considers the cell boundary to be a material similar to that of the fibers. This hypothesis agrees very well with what we know of the formation of the plasma membrane in the higher plants and asci, as will be seen later. It is perhaps the first suggestion on the part of investigators of the animal cell that the two substances are the same.

## Descriptive.

The present investigation was undertaken to attempt to determine in detail the exact sequence of events during the division of the cell body, and to correlate, so far as possible, the facts

[29] Zur Entstehung des Zwischenkörpers. Anat. Anz. **14**: 390.

[30] Ueber die Bedeutung der Polstrahlung während der Mitose u. ihr. Verhältniss zur Theilung der Zellleibes. Arch. f. mikr. Anat. **49**: 651.

thus brought out from the point of view of the physiology of cell reproduction.

## MATERIAL.

My observations were made largely upon (1) vegetative cells found in the growing root tips of various phanerogamic plants, among which may be mentioned *Allium Cepa*, *Lilium longiflorum*, *Fritillaria imperialis*, *Hyacinthus orientalis*, *Vicia Faba*, *Phaseolus vulgaris*, *Pisum sativum;* and (2) pollen mother cells of *Larix Americana* and *Larix Europæa*, and dividing pollen grains of *Iris versicolor* and *Hemerocallis fulva*.

In the first group I found the liliaceous plants were much more favorable for observation, and of these, owing to the ease with which the material could be obtained, *Allium Cepa* was the one generally used. I have satisfied myself, however, that the phenomena I shall describe occur in all of the plants mentioned, and my conclusions are of course drawn from a study of all of these plants. In many particulars there is a notable difference between the phenomena that may be seen in such tissues as the root tip and such cells as the pollen mother cells of the larch. These differences I shall attempt to correlate to some extent with the nature of the cells.

## METHODS.

As some of the phenomena herein recorded are at variance with those observed by previous investigators, I have thought it worth while to give a detailed account of the methods used, even though they are those already well known to cytologists. Various killing and fixing methods were employed. Flemming's chrom-osmo-acetic acid (both formulas); Hermann's platinum chlorid-chrom-acetic acid; Vom Rath's platinum chlorid-picro-osmo-acetic acid; Keiser's mercuric chlorid-acetic acid; 96 per cent. alcohol, and a mixture of mercuric chlorid, formalin, acetic and formic acids arranged by Professor D. C. Worcester, of the department of zoology of the University of Michigan, and soon to be published by him. Of these methods, the one best adapted to my purpose was the stronger solution of Flemming,

since the kinoplasmic portions of the cell in division were nearly always well fixed in it. It proved in this respect to be much superior to the weaker solution for the tissues studied. The material was kept in the killing fluid 30–48 hours, washed in running water, hardened by carrying through the different grades of alcohol and imbedded in paraffin in the usual way. Some care was necessary to avoid plasmolysis in the early stages of hardening. I found that the objects could not be left in the lower grades of alcohol for a very long time; 30 minutes in 15 per cent., 45 minutes in 30 per cent., and one hour in 50 per cent. seemed to be about the maximum limits. Above 50 per cent. more latitude as to time could be allowed.

Vom Rath's and Hermann's solutions generally fixed the material well, but were not so useful as Flemming's solution on account of the blackening of the tissue and the consequent difficulty in getting a clear differentiation in staining. The method of Professor Worcester was found to be useful for comparative purposes. For these tissues it has no other special value. Alcohol (95 per cent.) was irregular in its effects, sometimes giving well-preserved material but more frequently causing plasmolysis. The other methods were found generally unsatisfactory.

The sections (generally 5$\mu$ thick) were cut on a microtome and stained on the slides. The method best adapted to use in connection with objects killed in fluids containing osmic acid was the safranin-gentian-violet-orange method of Flemming. After removal of the paraffin the slides were placed in the safranin solution 25–30 minutes, rinsed in water, and then put into the gentian-violet solution 20–25 minutes. They were again rinsed in water and passed rapidly through a *weak* orange solution (1 part saturated solution orange G in $H_2O$ + 1 part $H_2O$), dehydrated, clarified quickly in clove oil, and mounted in balsam. For staining objects killed in the fluids containing mercuric chlorid, Zimmermann's fuchsin iodine green[31] and Heidenhain's haematoxylin, preceded by Bordeaux red as a ground stain, were found most serviceable.

[31] Morph. u. Phys. d. pfl. Zellkernes 6.

In order to show clearly certain zonal differentiations in the spindle as well as other general structures in the cells I have used photo-micrographs for many of the illustrations. I have considered this the more satisfactory, inasmuch as my preparations have showed some phenomena varying markedly from the descriptions of other observers.

## OBSERVATIONS.

For purposes of description we may group the phenomena under three heads representing three stages in the development of the cell plate, viz., *preparatory; genetic; growing.*

### 1. *The preparatory stage.*

At the time when the chromosomes have collected at the equator to form the equatorial plate the spindle is of the form that Hof has recently termed "monaxial," *i.e.*, a spindle having a single axis but not necessarily ending in single definite points as poles (*figs. 1, 10, 23*). The poles of the spindle in both the larch and the onion are in most cases somewhat blunt. In the latter plant my observations agree entirely in this respect with those of Hof (*l. c.*) and Nemec (*l. c.*). In the case of the larch I have not confirmed Strasburger's[32] observation of a centrosphere. In my preparations the poles generally appear blunt as they do in the onion.

The fibers which appear in connection with this stage may be grouped into three systems, connecting fibers, mantle fibers, and radiating fibers. These systems correspond in general to the system of fibers similarly named by older investigators, especially among the zoologists, except that here, as will appear later, the distinction cannot be so sharply drawn between connecting fibers and radiating fibers. If we study the above mentioned systems of fibers more in detail, it will appear that while many of the connecting fibers are collected into thick strands or bundles, and others appear as single fibers, such an arrangement does not indicate a necessary difference of character. Very frequently a single fiber diverges from a bundle and

[32] Karyokinetische Probleme *fig. 25.*

unites with another bundle or continues as a single fiber to the pole. The arrangement into bundles seems to be produced partly, at least, by the fibers being crowded into the small spaces between the chromosomes. This explanation is rendered more probable by the fact that, as Strasburger has pointed out, the arrangement into bundles is much more evident at the equator than in the polar regions of the spindle (*op. cit.*, p. 183), *i. e.*, the fibers forming a single strand often seem to diverge beyond the equator. Some of my preparations show that this divergence reaches to the ends of the strand (*fig. 23*), so that such strands are most compact where they are adjacent to the chromosomes.

The appearance of single fibers crossing obliquely from one bundle to another, together with the fact that such fibers often cross and recross each other, was taken by Belajeff as evidence that the fibers are drawn out portions of a protoplasmic net work. Guignard's observation that the number of connecting fibers is equal to the number of chromosomes may be explained by the hypothesis that the fibers are collected into larger strands in the spaces between the chromosomes. Guignard, as previously stated, described such fibers as secondary fibers formed by the lateral fusion of previously existing smaller primary fibers. He did not, however, distinguish any other than the connecting fibers. Strasburger later showed that there are other fibers extending from the poles to the chromosomes. These are the mantle fibers. They have been so clearly demonstrated recently by Osterhout, Mottier, Nemec, and others, that I need give no detailed description of them in this connection. Suffice to say, I find no apparent difference in structure between them and the connecting fibers.

The third system of fibers to which I have referred may be described briefly as including those which extend from the poles into the cytoplasm. They are much more abundant in the larch than in the onion; hence I shall first describe them as they appear in the former. They seem to have the same structure as the connecting or mantle fibers. Strasburger has figured them in the larch as radially arranged granules, while the connecting

fibers are shown as continuous lines. In my preparations the granular trophoplasm through which the fibers extend often has a radial appearance where the fibers are very abundant, but it is always possible in good preparations to distinguish the single threads (*fig. 23*). It is only by means of their distribution and arrangement that I would distinguish the radiating fibers from the other systems. They may be said to be centered in a general way on each pole, and to radiate through the cytoplasm in all directions toward the cell boundary, but at this stage very few appear to reach the plasma membrane. Their arrangement around the poles is by no means regular. Some of them lie across the poles in such a way as to have both ends free in the cytoplasm. With these it is of course often difficult to determine whether a single fiber is seen, or whether the appearance is given by two fibers extending from the same point in opposite directions into the cytoplasm. In many cases, however, I have been able to satisfy myself that a single fiber extended through the pole and that its two ends lay free in the cytoplasm (*fig. 23*). This was most evident in cases where the fibers lay in such positions as to form appreciable angles with the axis of the spindle. Where the apparent radiating fibers are continuous or nearly so with the long axis of the spindle it is often difficult to determine whether they extend through the poles into the region of the spindle itself or whether they end at the poles. In some cases it appears as if such fibers are merely prolongations of the connecting or mantle fibers. I could not be certain on this point on account of the abundance of fibers in the polar regions of the spindle. Some, however, may be traced through the poles into the cytoplasm closely adjacent to the spindle. Still it can be readily observed that many of the radiating fibers which lie closely adjacent to the spindle do not extend beyond the poles These latter fibers bear an interesting relation to the connecting fibers. They often extend from the pole parallel to the connecting fibers, even uniting with the strands of the latter, nearly to the equator, where they curve outward and end blindly in the cytoplasm. Many of the fibers from each pole cross one

another at the equator. These generally appear to be longer and more abundant than any of the other radiating fibers, but their identity in appearance with the connecting fibers makes it impossible in many cases to determine whether they extend to the poles or not.

From the above observations it seems to me to be improbable that there is any fundamental difference between the fibers of the three systems. While for convenience of discussion it is perhaps best to retain the classification heretofore used, it is worth while to understand clearly just what significance is to be attached to the different terms. By connecting fibers I mean those which lie entirely in the spindle and extend *across the equator*. Mantle fibers are those which lie entirely within the spindle and are attached to the chromosomes. The spindle is understood, then, to be made up of the mantle fibers and the connecting fibers. Radiating fibers are those which, connected in small part with the spindle, generally if not always at the poles have at least one end lying free in the cytoplasm. That this definition of radiating fibers may have to be slightly extended will appear later.

Whether there is any difference in origin of the various fibers I have not attempted to discover. The recent researches of Belajeff,[33] Osterhout, Mottier, and others, have indicated that all of the fibers have a common method of origin. Rosen,[34] however, believed from his study of spindle formation in the root tips of *Hyacinthus orientalis* that the connecting fibers are formed each by two fibers growing from opposite directions and fusing end to end at the equator. His observations have not been confirmed by later investigators.[35] So far as my observations go, in the onion radiating fibers seldom appear at this stage. Nemec, however, has described them as first appearing in the very early prophases and persisting through the metaphases. Their history, as Nemec describes it, is of much interest. The first

[33] Zur Kenntniss der Karyokinese be den Pflanzen. Flora **79**: 436. 1894.

[34] Kerne u. Kernkörperchen in meristematischen u. sporogenen Geweben. Cohn's Beiträge zur Biologie der Pflanzen **7**: 225.

[35] HOF, *loc. cit.*, and NEMEC, *loc. cit.*

indication of a spindle is an accumulation of hyaline substance around the nucleus, but in greater amount on the sides corresponding to the poles of the future spindle. The whole body thus forms an ellipsoid spindle fundament (*Anlage*). This soon shows a filar structure and in many cases these fibers extend outward from the sides and cross in the equatorial region of the cell. The radiating fibers thus appear prior to the other fibers, or it would perhaps be more accurate to say that they grow more rapidly, as rudiments of the other fibers appear at the same stage in the polar regions. It should be noted here that no radiating fibers are described for these early stages, except those extending toward the equator. Such fibers, however, reach to the plasma membrane and are attached to it. The attachment is shown by a small accumulation of violet-staining material at the point of juncture. While Nemec states that the above mentioned fibers persist throughout the process of nuclear division to the beginning of the anaphases, his figures of the equatorial plate stage do not show them, but in connection with the late metaphases they are again figured. It seems to me probable that the two sets of fibers are not identical. It is not unlikely that those first described changed their position and became connecting or mantle fibers, while the later radiating fibers are a new growth. Nemec himself states that he believes that some new radiating fibers are formed during the late metaphases. I have been able to see some radiating fibers in the onion in connection with the equatorial plate stage, but not in abundance nor of such length as Nemec described. They seldom reached beyond the equator. When they were present they showed the same relation to the other spindle fibers as has been described for the larch.

The appearance of the cytoplasm in this stage requires a brief description. In the onion, it surrounds the spindle closely and may often be seen between the fibers in the polar region. It is generally slightly denser in the vicinity of the spindle than it is nearer the cell-membrane. In older cells there are frequent vacuoles in the outer portion. In the larch an interesting differentiation frequently occurs. About midway between the cell

periphery and the spindle there is a thin layer of kinoplasmic material, looking as if it were made up of small portions of fibers in a tangled mass (*fig. 23*). A similar appearance was described by Mottier (*op. cit.*, p. 180) in an earlier stage of spindle formation in the pollen mother cell of the lily. He observed, however, that this layer forms a part of the spindle, *i.e.*, it is the same as the felted layer described by Strasburger and Belajeff. That it forms no part of the existing spindle in the larch, however, would be indicated by its late appearance after the spindle is formed. It may be that there is in the larch more kinoplasm formed than is needed for this stage in the development of the spindle, and that it becomes absorbed into the cell protoplasm or is used directly for the later stages in the growth of the fibers (p. 47.) Between this kinoplasmic layer and the spindle there often appears a thick layer of finely granular trophoplasm which stains readily with the orange. A similar layer in the pollen mother cells of Hermerocallis was described by Juel, but he he did not mention any strong affinity for the orange stain, such as I have observed in the larch. In some of my own preparations of Hermerocallis, I have observed the orange-stained layer very frequently.

Throughout the cytoplasm, and in some cases in the spindles also, there often appeared, in this as well as in later stages, large blue-stained granules. Their distribution was irregular. They were more apparent usually in the larch than in the onion, except during the metaphases, when they appeared very abundantly in the spindle of the latter. I shall discuss their appearance in connection with such stages in a subsequent paragraph.

In the early metaphases the connecting fibers appear of course much more plainly between the receding groups of daughter chromosomes. They can easily be traced through to each pole, thus being identified as the connecting fibers before mentioned and not as secondary structures formed simply between the groups of chromosomes. They show in the larch the compound structure before mentioned. In the onion, on the other hand, the portions between the receding groups of daughter

chromosomes often appear as single coarse fibers. This appearance is probably due to the closer crowding of the small fibers by the chromosomes. It is possible that in some cases this crowding together has gone to such an extent as to result in an actual lateral fusion of the fibers, such as Guignard suggested. The above-described condition of connecting fibers is doubtless what led Nemec to conclude that during the metaphases there were new coarse fibers formed reaching merely between the daughter chromosomes. I have been able to determine that in most cases the fibers can be traced through to the poles, and that they often appear to separate into smaller fibers beyond the chromosomes in the way described by Strasburger for the larch. In the larch, in which the fibers show their compound character much more clearly, the true relation is still more distinctly seen (*fig.* 2). While I have not been able to confirm the observations of Nemec (*op. cit.*, p. 329) as to the presence of secondary fibers during the metaphases which are formed merely between the groups of daughter chromosomes, I have often observed that the above-mentioned blue-stained granules appear to be very numerous in the region of the spindle. They often appear in rows and sometimes seem to be sticking to the connecting fibers. But such a regular arrangement is not at all characteristic. They are as frequently scattered in the ground substance of the protoplasm (*fig.* 25). That they are formed from disintegrating secondary fibers seems impossible to believe when we consider the fact that they may be scattered throughout the whole cell as described above. As to the function or ultimate fate of these granules I could learn nothing definite. They seem to be distinct from the ordinary granules of the trophoplasm in staining qualities alone. The fact that they showed most plainly in the region of the spindle may simply mean that they are more readily distinguished by form from the spindle fibers, which in this stage are not abundant, than they are from the other granules appearing in the cell.

While the above mentioned processes have been taking place in the connecting fibers, the radiating fibers and the cytoplasm

have undergone important changes. In the larch the radiating fibers apparently grow longer, so that by the time the chromosomes have reached the poles a great many of them may be traced to the plasma membrane. Any evidence of such a fusion of the fibers and the plasma membrane as Nemec described in the onion I was unable to find. In the equatorial plate stage the fibers certainly did not reach to the plasma membrane. Whether the difference in appearance of the radiating fibers is really due to the growth of the existing fibers or to the formation of new ones, I could not determine. In the later stages, shorter fibers may be seen, which are possibly the radiating fibers of the earlier stages, while the longer fibers are newly formed. The increase in number of fibers which such an explanation would demand was, however, not always evident in my preparations. In connection with changes in the radiating fibers there is a disappearance of the kinoplasmic layer heretofore described as lying between the spindle and the cell periphery. It may be, as previously suggested, that the substance is used in the growth of the radiating fibers, though I have no positive evidence that such a relation exists. The fine granular zone also disappears during the metaphases. There is now a tendency for the cytoplasm around the poles of the spindle to assume a finely granular appearance. The significance of such an appearance I have not attempted to explain.

In the onion the relation of the trophoplasm to the spindle remains practically the same as it was in the equatorial plate stage. When the diaster is formed there is a small number of connecting fibers, and the few radiating fibers that existed during the previous stage have not appreciably changed in appearance. During the later stages of the diaster, however, there is an apparent growth of new radiating fibers extending in all directions from the daughter nuclei. This phenomenon I shall discuss in a subsequent paragraph.

Following the formation of the diaster there sets in a series of activities which are concerned immediately with the formation of the cell plate. In the larch, the spindle soon appears to be

differentiated into three zones (*fig. 2*), as Went first pointed out in other forms. But I cannot confirm the statement that the darker subnuclear zones take their characteristic appearance from a stainable ground substance between the spindle fibers. A careful study of the preparation from which *fig. 2* was taken has convinced me that the darker portions are due to the structure and arrangement of the spindle fibers themselves. Some of the fibers are undoubtedly thicker in this region than in the equator (*fig. 27,a*). With this differentiation in structure is combined the fact that the bundles have here begun to separate into single fibers (*fig. 2*). The two processes taken together account for the extra density observed. The above facts seem to me to indicate that the kinoplasmic activity preparatory to the formation of the cell plate begins in the region of the nuclei. The thickened appearance of the fibers soon extends throughout their length (*figs. 3* and *27,b*). Concurrent with such thickening the separation of the bundles into single fibers continues until the central spindle has the same appearance throughout. By comparing *figs. 2* and *3* it can be seen that nearly all of the connecting fibers have apparently shortened slightly, leaving clear spaces just under the two daughter nuclei. In many cells there were often observed single connecting fibers in which the above described changes did not seem to be taking place, but they were never numerous in any one cell. Their distribution was not regular. They were as often seen in the central as in the more peripheral parts of the spindle. I shall have occasion to refer to them in the description of later stages. Granules of trophoplasm may often be detected among the ends of the connecting fibers at this stage. These have probably flowed in as the fibers contracted. The process of separation of the fibers described above gives the appearance of an increase in the number of spindle fibers. Whether such an increase actually occurs is doubtful. In the larch the evidence, so far as I have observed it, seems to show that the apparent increase is due entirely to the above mentioned processes. In this connection the hypothesis lately suggested by Strasburger, that the spindle fibers are increased in

numbers by splitting, is of interest. His evidence for the hypothesis may be stated as follows: (1) the apparent rapid increase in the number of fibers; (2) the fibers produce a rapid outgrowth of the cell plate; (3) they are often found lying closely side by side. The first and third points seem to me to be readily explained by the facts that I have already described for the larch, viz., the rearrangement of the fibers by the bundles separating into single fibers, and the shortening and thickening of the fibers, resulting in a spindle of denser appearance, with apparently more numerous fibers. Strasburger himself points out that the spindle fibers seem to separate from the daughter nuclei and to become thicker and more densely stained prior to the formation of a cell plate. It should be noted, however, that Strasburger had previously accepted Guignard's doctrine that the connecting fibers are secondary structures formed by the fusion of smaller primary fibers. The splitting of the fibers, in Strasburger's sense, would be essentially the same as the separation of fibers, as described above, with this one exception: in the former case the process is unlimited, for new fibers may continuously arise by the splitting of original fibers, but in the latter the process is limited by the number of fibers making up the bundles. If the splitting hypothesis were true, it would explain, as Strasburger suggested, the appearance of new peripheral connecting fibers, and thereby the growth of the cell plate; but below I shall describe phenomena which seem to indicate that the appearance of new peripheral fibers depends not upon such a multiplication of the original connecting fibers, but upon changes in some of the radiating fibers.

Concurrent with the above described changes in the connecting fibers, the distal portions of the radiating fibers that lie nearest the central spindle and cross at the equator seem to bend in such a way as to come nearer together and to give the appearance of bowed out connecting fibers; but that they are the previously described radiating fibers is evident from a careful study of the preparations. In *fig. 26* I have drawn accurately two such fibers extending one from each nucleus. Here the

relation is such as to indicate that the two fibers have fused laterally throughout a part of their length. Whether such a fusion is real or only apparent, I could not determine A careful study of the preparation from which the photograph for *fig. 2* was made shows all stages in the arrangement of radiating fibers, from that shown in *fig. 26* to that in which the fibers extend out into the cytoplasm and cross at the equator in such a way as to form sharp angles (*fig. 24*). The significance of these facts I shall discuss in a later connection. The radiating fibers that do not cross at the equator, so far as I could determine, have suffered no appreciable change. It is important to keep in mind that, with the exception of the presence of the trophoplasmic granules, the changes in the appearance of the spindle which have so far taken place in the larch are due mainly to changes in the existing spindle fibers themselves, and not to the addition of new fibers or of other material.

If we turn now to the onion, we note that there is an apparent increase in the number of connecting fibers (*figs. 12, 13, 14*). *Fig. 13* represents the same stage in the onion as that represented by *fig. 2* in the larch. The slight differentiation of the spindle into zones may be seen. While the smaller number of spindle fibers renders such a differentiation less conspicuous, it is evident that it is caused in the same fashion as in the larch. A fact of importance to note here is that there are now visible more radiating fibers than could be seen in earlier stages. The photograph has not brought these out very clearly, but they may be seen by close inspection. These fibers radiate in all directions from the nuclei, but those are more abundant which extend toward the equator. In this connection it may be worth while to point out that these new fibers do not bear exactly the same relation to the spindle as the radiating fibers that exist in the equatorial plate stage. Those were centered not on the nuclei or chromosomes but upon the poles of the spindle. It is possible, however, that they were originally centered upon the mother nucleus, as previously suggested. From a careful comparison of this with earlier stages, I am convinced that there

has been a growth of new fibers. It is not impossible that some of these extend into the central spindle, thus increasing the appearance of zonal differentiation, but I could not establish this by actual observation. In an earlier paper Guignard figured such a relation but did not describe it. It seems to be not improbable that such a condition may exist, and that such fibers may grow in length and form new connecting fibers, either by fibers from the opposite nuclei fusing, or by a continuous growth from one nucleus to the other. This process would account for the apparent increase in number of connecting fibers. Still the evidence is too meager to lead to any definite conclusion. There is no convincing evidence that there is any real increase in the number of connecting fibers. Its appearance may be due entirely to the changes which take place in the original fibers, as is the case in the larch. On the other hand, the relatively small number of the connecting fibers in earlier stages seems to show that some new ones have been formed. The question needs further investigation. If there are new connecting fibers formed they seem to act simultaneously with the original fibers in the process of forming the cell plate. The point that seems of most importance to me here is the previously described relation of the radiating fibers to the daughter nuclei, *i. e.*, that they center not upon the poles of the spindle but upon the nuclei themselves. This relation, combined with the fact that the fibers are new formations, may indicate that the nuclei are the metabolic centers for the formation of spindle fibers. Such an hypothesis is further strengthened by the previously described changes in the connecting fibers in the larch, where the increased thickness is first evident near the ends of the fibers, *i. e.*, in those portions nearest the nuclei. The fact that the appearance of the new fibers comes prior to the reconstruction of the daughter nuclei does not invalidate the above hypothesis, for, as Juel has shown in the formation of abortive pollen grains in *Hemerocallis fulva*, single chromosomes may have spindles formed between them and the normal nucleus. Here would seem to be a case in which a chromosome as such

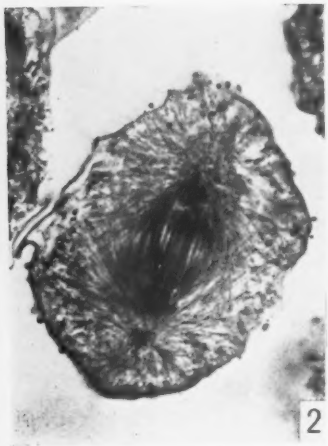
acts as a center for spindle formation. While the recent contributions on the subject of spindle formation in higher plants vary greatly in detail they all agree in one particular, viz., that the first indications of a spindle are to be found in connection with the nucleus and that the subsequent prophases take place while the fibers remain in this connection. These facts may be explained by the hypothesis that the nucleus is the center for the formation and activity of the kinoplasm.

The further history of the equatorial zone in the onion presents a striking difference from its history in the larch. Whereas in the latter it disappears with the rearrangement and change in the connecting fibers prior to the formation of the cell plate, in the former it soon becomes filled with a substance that stains strongly with the orange of the triple stain. The spindle fibers retain their violet color in the same regions, showing that the orange stain is taken by a substance foreign to the fibers (*figs. 14, 15, 28*). In appearance this substance is entirely homogeneous. I could detect no appearance of granules or any other definite structural elements in it. It would seem to be a substance in solution in the living cell. It is a significant fact that the cell walls showed the orange stain in those preparations in which this orange stained substance is most evident in the spindle. In many preparations in which there was a slight excess of violet, the cell walls were stained blue and the substance in the equatorial zone could scarcely be distinguished from the surrounding blue stained protoplasm. By the use of other stains it was often difficult to color or differentiate this substance. In one preparation, stained with eosin and methyl green, in which the methyl green was in excess, all parts of the cell were stained green except the equatorial zone and the cell walls, both of which showed a slight tinge of eosin. In all of the stains used when both the cell wall and the interfilar substance were stained, their color was the same. There were some cases, however, in which the walls were stained while the equatorial zone remained colorless, *e. g.*, slides stained in ruthenium red or iron haematoxylin.

The similarity in staining of this substance to that of the cell walls, together with its presence in the region of the spindle in which the cell wall appears later, I have taken to signify the presence of a carbohydrate substance destined for the formation of the new cell wall. Whether it is at all analogous to the previously described layer around the spindle in the cytoplasm of the larch, I am not able to say. The fact may be of some significance in this connection, that in a late stage of division in the larch a similar orange layer appears in the cytoplasm around each daughter nucleus. Possibly it shows the presence of material destined for the formation of the walls of the pollen grains. This fact may be correlated with the fact that the division of the pollen mother cell often does not follow the first nuclear division. But in the stages showing the young permanent cell plate, such a substance was generally invisible, though in some cells a slight indication of it was seen. There would seem to be in these cells very slight or no aggregation of reserve cell-wall material. It is interesting to note that in the dividing pollen grains of Iris and Hemerocallis no orange stained interfilar substance was seen. Here, of course, there is no cell wall formed between the two cells.

The relation of the spindle fibers to this orange substance is worthy of notice. As above mentioned, they retain their characteristic color, but they often appear greatly attenuated in this region. It would seem that the substance had crowded them into such a condition (*figs. 28, 29*), and that it retarded the previously described processes of thickening and separating of the fibers.

The staining qualities of the interfilar substance agree with what Farmer and Williams have described for the protoplasm of the neutral zones between the daughter nuclei of the future oospheres of Fucus. In the Saprolegniaceæ Trow has suggested that the so-called cellulin granules are a form of reserve cellulose, which may be used to close the opening made by the breaking of a hypha. I have seen preparations of Saprolegnia in which the young cell wall cutting off the sporange stains strongly with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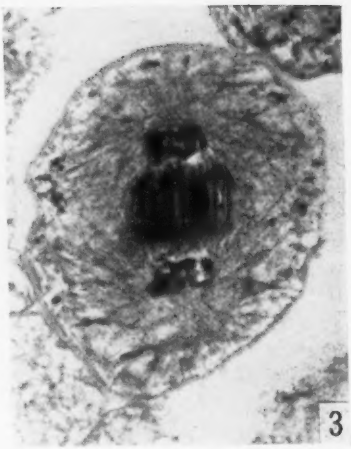
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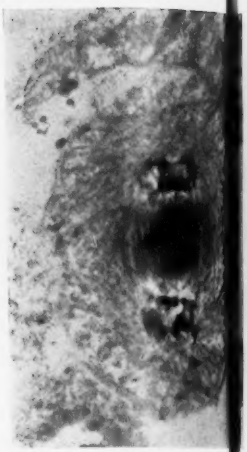

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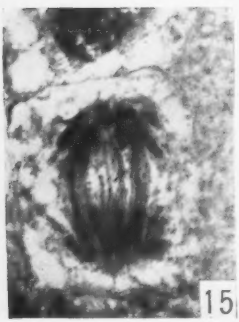
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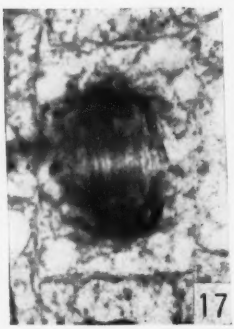
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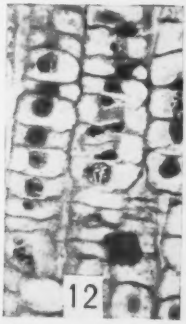
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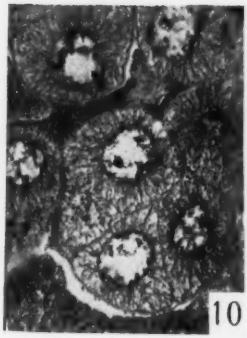
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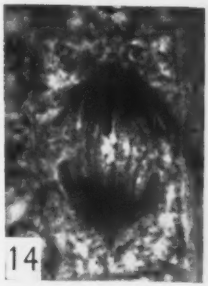
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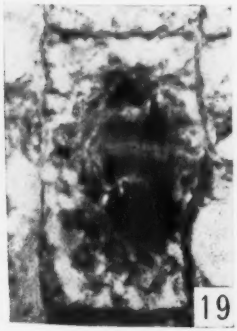
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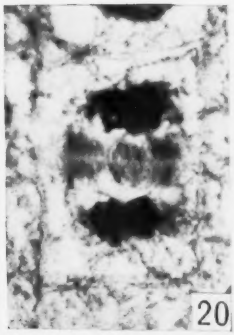
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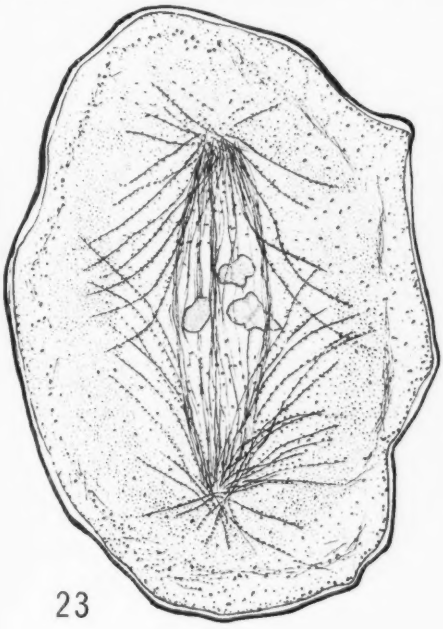
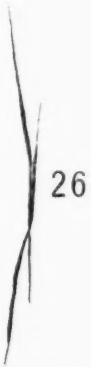
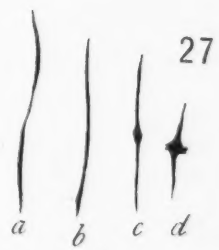
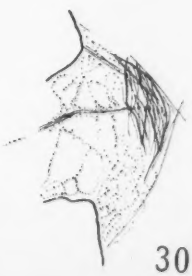
BERLA CELL PLATE








TIMBERLAKE on CELL PLATE

orange, and strongly orange stained granules are often apparently imbedded in the adjacent thick plasma membranes. The above facts seem to indicate that there may be in the protoplasm some form of reserve carbohydrate in readiness for the formation of a cell wall. I shall hereafter use the term carbohydrate material in speaking of the interfilar substance. The further history of this material is connected with the subsequent stages in the development of the cell plate. The essential difference thus far between the larch and the onion is that in the former the processes preparatory for cell division have been mainly carried on in the already existing fibers, while in the latter there has been a formation of new fibers and an aggregation of carbohydrate material in the equatorial region of the central spindle.

UNIVERSITY OF WISCONSIN.

*(To be concluded.)*

# CONTRIBUTIONS FROM THE CRYPTOGAMIC LABORATORY OF HARVARD UNIVERSITY. XLIV.

## NEW OR LITTLE KNOWN UNICELLULAR ALGÆ. I. CHLOROCYSTIS COHNII.

GEORGE THOMAS MOORE.

(WITH PLATE X)

EVER since the discovery by Cohn, in 1872, of the chlorophyllous endophyte, *Chlorochytrium Lemnæ*, there has been considerable interest in algæ having such a habit, and much speculation has been indulged in, both as to their affinities and the method whereby they acquired their peculiar condition.

Probably the first recorded instance of a green alga living within the tissues of a host was that described by Mettenius (**13**) in 1850. This author found that in the fronds of *Polyides rotundus* (Gmelin) Grev. were curious green cells which were more or less crowded together and completely surrounded by the substance of the alga. These cells Mettenius considered to be the mother cells of the spores of Polyides, but Cohn (**1**) thought it more likely that they were young plantlets of some grass-green alga. Thuret (**1**) in a letter to Cohn confirmed this view and identified the plant as *Cladophora lanosa* (Roth) Kütz. He explains that he found the germinating zoospores within the cortical tissues of the Polyides, which gradually increased in size without dividing. Towards the end of the winter, however, they elongated rapidly, breaking through the tissues of the Polyides, and developed into small Cladophora tufts. Cohn found similar plants at Heligoland, but did not observe that they became septate or grew through the tissues of the host plant; hence he regarded them as being distinct endophytes. Some years previous to this, Cohn (**2**) described some long, narrow, green cells which occurred among the densely packed filaments of *Petrocelis cruenta* J. Ag. He at first regarded these as the

normal reproductive cells of the Petrocelis, but later came to consider them as something quite separate from this plant. These green cells growing with Petrocelis have been found in this country by Dr. Farlow (**6**), and recently Kuckuck (**11**) has decided the plant to be a Codiolum, having no distant connection with its supposed host.

After Chlorochytrium was described on Lemna a number of endophytic forms were discovered, some of which showed such marked resemblances to certain fungi that, had it not been for their green color, they would undoubtedly have been placed within that group. One of these "green parasites," as they were popularly termed, was found by Wright (**17**) in 1876 growing on various algæ off the coast of Ireland, and called by him *Chlorochytrium Cohnii*. The discoverer of this form was so impressed with its fungus-like appearance and habit that he devoted considerable space to the discussion of how the plant was in reality a fungus which had but recently acquired the property of manufacturing chlorophyll. He was even able to observe the stages in this process as the plant developed. It is not my intention to go into a discussion of how fungi and endophytic algæ are related to each other; I merely wish to describe one of the algal forms, and any comparisons to be made with the fungi must be left to another time.

While collecting along the beach at Lynn, Mass., in February 1897, my attention was attracted to the peculiar granular appearance of some Enteromorpha which was growing attached to piles. When brought into the laboratory and examined under the microscope, the alga was seen to be covered with a green unicellular organism which at first did not seem to have been previously described. Upon more careful examination and an exhaustive search of the literature upon the subject, it was thought that this plant must be the endophytic alga found by Wright, *Chlorochytrium Cohnii*. The material collected by me, however, did not perfectly agree with any published account of this species, and according to the keys in both De Toni (**3**) and Engler and Prantl (**5**) could not find a place within that genus.

It seemed necessary, therefore, to study the structure and development of the plant more carefully before it could be decided whether or not it really was a new genus.

Since the plant was discovered by Wright, there have been but three published accounts of this form, for, although it occurs in widely separated regions and upon a number of different hosts, it is but rarely collected. Lagerheim (**12**) in 1884 found it off the coast of Sweden, and the next year Reinhardt (**14**) came upon it near Sebastopol, while investigating the flora of the Black Sea. The latter observer considered that the variations in this form from that of the original Chlorochytrium described by Cohn were sufficient to place it within a new genus, and he consequently proposed the name *Chlorocystis* which it has since borne. In 1892 de Wildeman (**4**) secured material from off the coast of France and published a short account of the plant. It has been reported from Greenland by Rosenvinge (**15**) and a new species growing on *Sarcophycus potatorum* has been described by Miss Whitting (**16**).

The material collected at Lynn frequently showed the Enteromorpha to be so nearly covered by the Chlorocystis as to cause it to appear rough and somewhat distorted even with a hand lens (*figs.* 1 and 2). The smaller more delicate pieces of the host plant seemed to be a more favorable resting place for the unicellular alga, and it was only occasionally that an individual was found upon the larger more exposed plants. The only reason discernible for this was the fact that the Enteromorpha was exposed to the air except at high tide, and the smaller fronds, growing in tufts and more closely adhering to the piles, retained the moisture longer and were consequently more favorable for growth.

When viewed with the ordinary low powers of a microscope, Chlorocystis appears a bright green color, usually of exactly the same shade as the Enteromorpha cells, but is not easily mistaken for them. If the cells of the host plant are dividing to form branch-like outgrowths and project above the surrounding tissue, there is a slight resemblance to the young

Chlorocystis, but a careful examination will at once reveal the difference.

In shape *Chlorocystis Cohnii* is usually spherical, although it may be slightly elliptical. It measures from 16–26$\mu$ in the mature condition. Even though the plants are frequently crowded together in irregular masses, they never lose their characteristic outline.

The question as to the degree to which Chlorocystis may infest the host plant is one upon which my observations do not agree with those made previously. Both Lagerheim (**12**) and de Wildeman (**4**) describe the plant as being completely surrounded by the cells of the host, except for a small colorless portion which projects beyond the surface, through which the zoospores escape. Wright in his original description conveys the same idea, although he says, "sometimes zoospores attach themselves in such quantities to Schizonema that there is no room to force themselves into the frond," and at such times they are said to show but little evidence of penetrating the host. *Chlorocystis sarcophyci* (**16**) is described as being completely embedded within the tissue of Sarcophycus. As may be seen from *fig. 2*, the plants as I found them were not always included within the host, but were quite as often merely attached to the surface of the Enteromorpha. While, as will be described later, the zoospores upon germination may send out processes which penetrate between the Enteromorpha cells and during further development may be more or less surrounded by these cells, the fact remains that many of the plants pass their entire existence without having at any time been within the tissues of the host. The crowded condition of which Wright speaks is not necessary to bring this about, for the epiphytic habit is just as apt to occur among single individuals entirely separated from one another, as when they are grouped together. Even when the lower half of the Chlorocystis cell is below the Enteromorpha (*fig. 5, b*), a firm but gentle pressure will usually free it, leaving a round clear space where it has crowded the host cells apart. At no time were cells observed completely covered by the Enteromorpha,

and the impossibility of such an occurrence is easily understood when we remember that the single layer of Enteromorpha cells is frequently less than half the size of the Chlorocystis, and that they could never any more than surround the alga in a very superficial way. When the host is a plant made up of a mass of tissue, it may be that Chlorocystis assumes a true endophytic habit, but in Enteromorpha it certainly does not seem possible. Occasionally zoospores get between the tubular frond of the host through some accidental opening and there develop into normal Chlorocystis cells, just as they would on the surface of the plant, but this can hardly be called endophytic.

There is no evidence that the Enteromorpha is inconvenienced in any serious way by the presence of the Chlorocystis. Even when the fronds were almost completely covered, the cells of the host plant retained their normal appearance and seemed to be capable of carrying on all their functions. *Chlorocystis sarcophyci*, according to Miss Whitting (**16**), exerts a direct influence upon the surrounding tissue, "causing at first a swelling and loosening of the tissue, and finally complete disintegration of the cells," but nothing of the kind takes place with *Chlorocystis Cohnii*. The only benefit the Chlorocystis seems to derive from its host is that of a convenient and easy place of attachment, the condition well expressed by the German term *Raumparasitismus*. The algæ upon which *Chlorocystis Cohnii* have been found are quite various. *Enteromorpha* and *Urospora* among the Chlorophyceæ; *Polysiphonia* among the Rhodophyceæ, *Ascophyllum* among the Phæophyceæ, and *Navicula* (*Schizonema*) among the Diatomaceæ have all been recorded as host-plants for this form. The hydrozoan, *Campanularia*, and the infusorian, *Vaginicola*, have also been found with Chlorocystis growing upon them, and it seems not unlikely that the peculiar condition described as the abnormal fruit of *Calothrix confervicola* by Harvey (**7**) and the abnormal cells of *Prasiola leprosa* figured by Jessen (**8**) may likewise be due to this alga.

Chlorocystis contains a single large chromatophore, which, according to Reinhardt (**14**), and Wille in Engler and Prantl (**5**),

is said to lie always upon but one side of the cell. This is not true, however, and it was only after a considerable number of specimens were examined that the "one-sided" chromatophore was observed. It so happened that all the specimens which were first found showed a chromatophore completely lining the cell wall, as indicated in *figs. 1, 2,* and *4*. Later, however, examples were found more nearly resembling Reinhardt's figures (*figs. 3, 5a*); but while this condition frequently occurs, it can no more be considered characteristic than when the whole cell is lined. A large and easily discernible pyrenoid lies near the surface of the cell and can be followed through all the subsequent divisions of the chromatophore (*figs. 6, 7*). Material killed in picric acid and stained for some time in 2 per cent. acid fuchsin brought out the pyrenoids well, although Flemming's fluid with iron-alum-haematoxylin gave perhaps more satisfactory results. The chromatophore usually forms a definite dome-like thickening where it surrounds the pyrenoid, and this may extend into the cell in the way shown in *fig. 5a*. When the chromatophore does not entirely line the wall, it radiates from the pyrenoid in irregular bands or ribbons, and these frequently do not pass more than half way round the cell (*fig. 5a*). This is the condition which Reinhardt figures and which he considered a generic characteristic. It was thought for a time that cells in which the chromatophore formed a complete lining might represent a condition subsequent to the formation of zoospores and not really be the adult Chlorocystis. Cultures in a Van Tieghem cell did not give much information on this subject, for although zoospores would be formed and escape, they did not develop to anywhere near maturity. This was probably due to an insufficient supply of oxygen, for when cultures were made in Ward cells, or simply under large cover glasses kept in a moist chamber, the zoospores could be watched from the time they escaped until they attained their full development. By this means it was settled beyond a doubt that in the great majority of cases the chromatophore entirely lined the cell from the beginning, and that it was a perfectly normal arrangement throughout all the vegetative stages of the plant.

Near the center of the cell is a well-defined nucleus, from which the protoplasm radiates in fine strands. There are usually several small non-contractile vacuoles present and the whole cell contents is often quite granular.

Two sizes of zoospores are formed. The larger ones, which are spherical, measure 6–7 $\mu$ in diameter (*figs. 10, 12*), while the smaller are only 2.6–3.5 $\mu$ and are somewhat pyriform in outline (*figs. 11, 13*). The method of the formation of the zoospores is identical in both cases, except that there are more successive divisions in the formation of the smaller spores, thus producing a greater number. In the original description of the genus by Wright, it is stated that the zoospores are formed in a very few hours by free cell formation. By Reinhardt (**14**) this simultaneous formation is considered one of the points of distinction between Chlorocystis and Chlorocytrium. De Toni also uses this distinction to separate the two genera. That the zoospores in Chlorocystis are formed by free cell formation is undoubtedly wrong, and all of my observations go to substantiate those of Lagerheim (**12**) and de Wildeman (**4**), who both state that the spores are formed by successive divisions. All stages in this process may be observed (*figs. 6, 7, 9*), and nothing comparable to the description by Wright has ever been seen. Also the statement made by the discoverer of the genus that the zoospores are at first colorless and that the protoplasm seemed to project itself to one pole and there form a single cilium is not borne out by my observations. Both kinds of zoospores have each four cilia, with a single chromatophore lining the base of the cell. In the large zoospores the pyrenoid is easily made out, and in the hyaline end of both the large and small spores is found a lenticular or spherical red spot.

When the zoospores are fully formed and ready to escape, a circular piece about 10 $\mu$ in diameter is cut out from the top or outer side of the cell. This may be entirely loosened, or frequently it simply turns back, remaining attached at one side (*fig. 11*) very much as in some of the Chytridineæ. It seems probable that the zoospores do not always escape in this manner,

for all the other observers of this plant have spoken of a colorless neck which projects beyond the surface of the cell and through which the zoospores make their way. Wright, however, has said to Miss Whitting (16) that when he found *Chlorocystis Cohnii* developed in the interior of tissue, the cells were sometimes quite globular. Certainly the figures of Lagerheim (12) and Reinhardt (14) do not correspond to the description of a plant possessing such a protuberance. If the *Chlorochytrium inclusum* of Kjellmann (9) is finally to find a place within the genus Chlorocystis, as has been suggested, we have still another example of a form without the neck-like protuberance. After the examination of dried specimens of *Chlorochytrium inclusum* Kjell. I am not inclined to think that it is a Chlorocystis; although the published figures are strongly suggestive of that genus. It is certain that at no time, among the hundreds of specimens of Chlorocystis which were examined, was there anything that resembled a colorless protuberance. It may be that the varying habitat has something to do with the difference in aspect which this alga often presents; at any rate it seems probable that the presence or absence of a colorless tubular portion through which the zoospores may escape is not of much importance.

When the zoospores are liberated they swim about for a length of time varying from a few minutes to two hours. No difference was discernible in the rate or length of activity of the two kinds of spores. In almost every case the spores escaped perfectly free and independently of each other, but in a very few instances it appeared as though they might have been enclosed in a delicate membrane as in Chlorochytrium. If there was such a membrane it must have been very frail and was suggested rather by the arrangement of the zoospores than by any actual observation. It always seemed to break up before any reagent could be added to demonstrate it, and it is quite possible that nothing of the kind exists. Such a membrane enclosing the zoospores could not be of any significance from a systematic standpoint, for even in forms where it occurs frequently, there are conditions which bring about its total disappearance.

Material in the laboratory showed the time for the escape of the zoospores to be usually from seven to ten o'clock in the morning. This probably varies with the changing conditions at the seashore, and since the alga was submerged for only a few hours twice a day, it seems likely that the time of zoospore discharge varies with the tides. Efforts to establish this fact were unavailing. Observations made during the night were likewise without result. Perfect aeration was found to be conducive to the formation and discharge of large numbers of zoospores.

The existence of two kinds of zoospores and the fact that conjugation takes place in certain closely related genera would naturally lead to the supposition that something of the same kind occurs in Chlorocystis. De Wildeman (**4**) quotes Lagerheim as having observed copulation, but I am unable to find such a statement in any of Lagerheim's papers. He does mention having seen two kinds of zoospores, and considers it probable that the larger spore is formed by conjugation, but I think does not claim to have seen the process. From my own observations I can say that it is certain the larger zoospores are not formed by conjugation, and that it is possible for both sizes of zoospores to develop into new plants without any fusion. This point was carefully investigated by means of Van Tieghem cell and other cultures, and the zoospores were observed during their escape and final coming to rest. There was at no time any appearance of conjugation, and the development of the spores, whether of the large or small variety, was always the same, the cells produced being similar in every particular to the characteristic adult plants. It may be that under different physiological conditions conjugation might occur, but at the present time no light can be thrown upon that point.

When a zoospore comes to rest upon the surface of the host-plant, its cilia disappear and a thin gelatinous wall is formed around it. The red spot is lost to view and the pyrenoid becomes more prominent. If the zoospore is to develop within the host instead of merely attaching itself to the surface, a short

colorless neck is pushed out, and this penetrates the Enteromorpha frond between its cells and pushes them apart. When an entrance has been gained in this manner, the neck widens until the whole cell appears funnel-shaped, and this, after further growth, assumes its mature spherical condition. In a few instances zoospores were observed which had germinated without having come in contact with the host-plant, and it is an interesting fact that some of these sent out colorless tubes of a considerable length (*fig. 8*). These were all found in cultures of various kinds and may have been due to some unknown abnormal condition.

In the first published account of this plant, the zoospores were described as escaping from the mother cell without possessing any color. These colorless zoospores developed into colorless plants which remained so until they had nearly reached adult size when the protoplasm commenced to develop "green cromules." "These cromules," says Wright (**16**), "arise as minute points along the inner surface of the cell wall from whence they radiate to the nucleus giving the appearance of a number of necklaces hung in loops." Although I looked carefully for some such condition in my material I was unable to observe anything abnormal or unusual. The green zoospores gradually developed into mature green plants with definite chromatophores as described.

Resting spores were observed in material that had been kept in the laboratory for some time and had been allowed to dry up partially. They are formed by the thickening of the wall of the mature plant and the contents rolling itself into a solid mass of irregular outline. The spore thus becomes of a darker green shade, and the pyrenoid is lost in the increased density of the ceil contents.

It will be seen from the foregoing that a number of points with regard to the structure and development of *Chlorocystis Cohnii* which have been considered by former investigators as characteristic can no longer remain as such. The habit of the plant is variable, and it certainly cannot be regarded as a universal endophyte. The chromatophore is quite as apt to line

the cell wall as to be confined to one side and the radiate arrangement of the coloring matter may or may not occur. The method of zoospore formation is certainly the same as described by Klebs (**10**) for *Chlorochytrium Lemnæ*, namely by successive division. Even the manner in which the zoospores escape seems to vary, and the presence or absence of the colorless tube is of but little consequence.

It may be questioned whether or not the material found at Lynn really was Chlorocystis, since it fails to agree with any published account. Certainly much the easier way would be to regard it as a new genus. But while the plants found do not agree with the keys in de Toni, and Engler and Prantl, or with any other published account, the points of resemblance are very marked when all the literature is considered as a whole and the various generic characteristics correlated. The few papers on the subject are strangely at variance, and the figures in at least one case do not agree at all with the accompanying description, nor with the specimens distributed by the author. Consequently it seems a case where we are justified in disregarding certain published accounts and in considering that the form above described is really what Wright and Reinhardt meant for the plant *Chlorocystis Cohnii*.

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## EXPLANATION OF PLATE X.

All the figures are from ink drawings sketched in with an Abbé camera. In the reproduction they are reduced one fourth. *Figs. 1* and *2* are drawn with a Leitz $\frac{1}{6}$, oc. 3. All the others with a Leitz $\frac{1}{12}$ (oil), oc. 3. The magnifications given are the original ones before reduction and allow for projection.

*Chlorocystis Cohnii* (Wright) Reinhardt.

FIG. 1. General habit showing appearance of cells in Enteromorpha frond. × 280.

FIG. 2. Section through Enteromorpha showing relation of Chlorocystis to its host. × 280.

FIG. 3. Surface view of single cell. "One-sided" chromatophore with pyrenoid and radiate arrangement. × 830.

FIG. 4. Surface view of single cell with chromatophore lining entire wall. × 830.

FIG. 5. Side view; *a*, showing arrangement of radiating "one-sided" chromatophore; *b*; zoospore which has come to rest directly over Enteromorpha

cell; *c*, developing zoospore with projecting neck penetrating between Enteromorpha cells. × 830.

FIGS. 6, 7. Surface views of first two stages in the formation of zoospores. × 830.

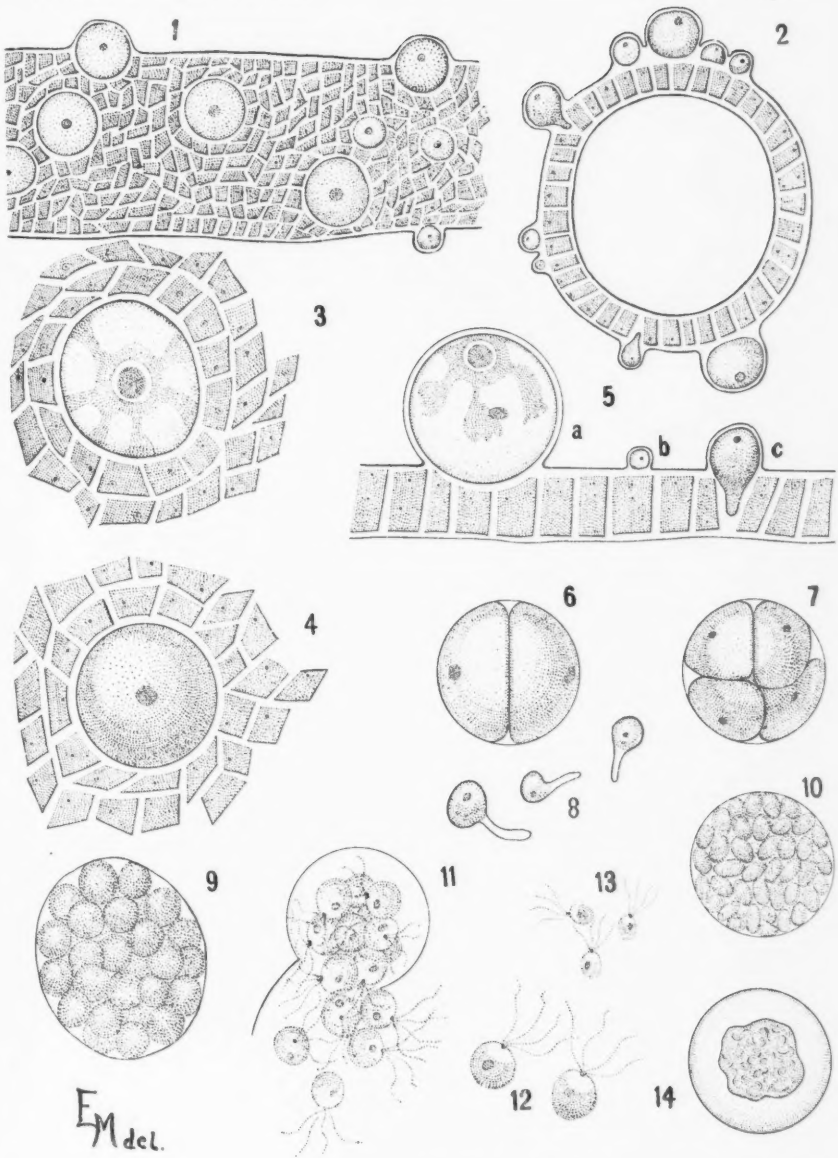
FIG. 8. Germinating zoospores in cultures not in contact with host. × 830.

FIGS. 9, 10. Sporangia of large and small zoospores respectively. × 830.

FIG. 11. Sporangium of large zoospores showing method of discharge. × 830.

FIGS. 12, 13. Large and small zoospores. × 830.

FIG. 14. Resting spore.




MOORE on CHLOROCYSTIS

# BRIEFER ARTICLES.

## NOTE ON THE MECHANICS OF THE SEED-BURYING AWNS OF STIPA AVENACEA.

(WITH FIVE FIGURES)

In the parts of many plants where hygroscopic movements take place in dead tissues, the cause is found in thick-walled mechanical cells of peculiar structure or varying chemical composition.

The ripe and dry awn of *Stipa avenacea*, holding the seed at the lower end, is strongly twisted over half its length next to the seed in a direction opposite to the movement of watch hands. The remainder of the awn, not having the spiral structure of the former, is not twisted, but is bent at an angle to the body of the awn, thus furnishing a brace or support when the seed begins its boring motion, driven by the alternate twisting and untwisting of the dry or wet awn. Little barbules on the upper part of the awn directed away from the seed, assist its progress forward while preventing any backward movement.

The seed is tipped with a short, sharp point, slightly curved, the better to lead the way into the ground. Stiff hair-like barbs on the lower portion of the seed hold it in the ground when once started. The onward motion is still farther assisted by the increased length of the awn when wet, which amounts, by actual measurement, to 20 per cent. of the whole length. On drying a corresponding withdrawal of the seed is prevented by the barbs. So the alternate wetting and drying of the awn serves the twofold purpose of moving the seed about (although this is, no doubt, more commonly accomplished by being fastened with its appendages to some moving object) and placing it in a favorable position in the earth for germination.

The awns of Avena act much more promptly than those of Stipa; the latter take several minutes to straighten out in water, while one of *Avena barbata*, thrown on water, made five or six turns in twice as many seconds. The moist awn straightens out completely. When placed in caustic potash or other macerating fluid it twists with watch

hands almost as strongly as it does in the opposite direction when dried.

The minute structure of the awn furnishes an explanation of the phenomena here described. A thorough investigation of this subject was made by A. Zimmerman[1] whose purpose was to gain a more accurate insight into the torsion mechanism of the awns of wild grasses. He gives Hildebrand credit for first attempting to explain mechanically the hygroscopic torsion. His explanation was considered incorrect, and was not in accordance with the views of Nägeli and Schwendener, who held that the seat of the mechanism is in the individual cell. Francis Darwin afterward confirmed this view. Zimmermann found that in the awn of *Avena sterilis* (with which, he says, *Stipa pennata* agrees in all essentials), the twisting power is confined solely to the outer row of cells whose structure shows a spiral arrangement. Both the arrangement of the pits in the walls of these cells and the appearance of the material in polarized light evince their spiral structure. The cells within this outer row have no tendency to twist, but the author thinks they assist the general movement by their contraction on drying. While so far little account had been taken of the micellar arrangement in the cells, the explanation of the mechanism was thus carried back to the molecular structure of the cells.

The present observations confirm those of others in locating the cause of the twisting of the awn in the individual cells *and show that not only a layer of cells but all of the mechanical cells are active in bringing about this result.*

As is well known, the twisted portion of the awn is composed principally of sclerenchyma cells with a fibro-vascular bundle in the center and a band of chlorophyll bearing tissue on each side (*fig. 1*). The latter, however, has nothing to do with the torsion. A striking peculiarity of the mechanical cells is the narrowness and eccentricity of their lumina; furthermore, this eccentricity in all the cells is alike, so that the lumina lie nearest the center of the awn (see *figs. 1* and *3*).

Strong Schultz's solution shows that the material immediately around each lumen is still very much like cellulose; that it swells and contracts more than the outer and denser layers of the cell wall is evident, since the surface of a cross section of a single cell in caustic potash is convex, but when washed and dried is concave.

[1] Jahrbücher für wissenschaftl. Bot. **7**: 542.

As before stated, Zimmermann inferred the spiral arrangement of the material in the walls of the outer cells from the direction of the pits, and from the appearance in polarized light; but according to him no one had succeeded in bringing out clearly any striation.

After treatment with strong caustic potash and then with dilute glycerine, I found such striations quite well marked, passing obliquely

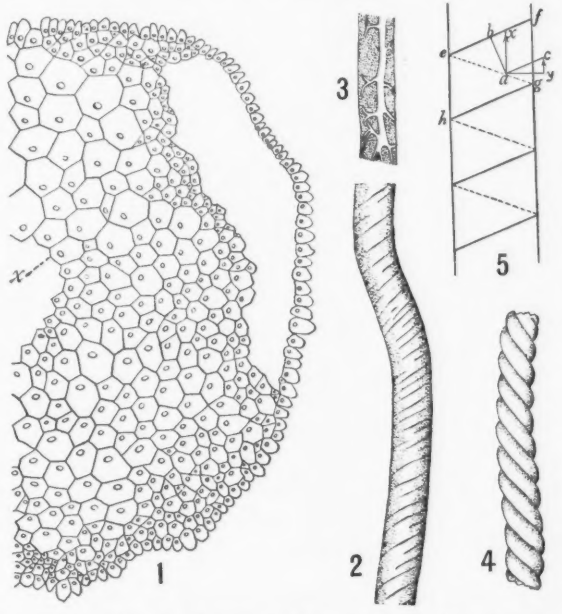



FIG. 1. Cross section of half an awn showing the disposition of the mechanical cells.— FIG. 2. An isolated cell (dry) showing the spiral arrangement of the material in normal condition.— FIG. 3. An optical longitudinal section of one of the cells ($x$) shown in figure 2.— FIG. 4. One of the cells after soaking in a macerating agent.— FIG. 5. Diagram showing the resultant of forces that may cause torsion in the mechanical cells.— FIGS. 1, 3, and 4 are enlarged 115 times.

across the cell (*fig. 2*). When seen through the cell in the opposite wall, they pass in opposite direction to those in the wall on the nearer side. This makes patent the spiral structure of the cell wall, denser (more highly refractive) layers alternating with layers which are less dense.

That the outer layer of cells is not, in this case at least, exclusively instrumental in effecting torsion, was proved by scraping off the outer two thirds of a wet awn, when the remaining central portion, on drying, was seen to twist as perfectly as the intact awn. Another evidence of this fact is, that after maceration, the largest cells, which belong to the middle portion of the awn, are found twisted quite as much as the smaller outside cells (*fig. 4*). This also agrees with Darwin's observations, quoted by Zimmermann (*l. c.*, p. 551).

There can be no doubt, then, that the mechanism is in the individual cells, and in the inner as well as the outer; and we have as an explanation of the hygroscopic torsion, thick-walled mechanical cells, each with very small eccentric lumen which is surrounded by a layer of cellulose-like material, the molecular structure of which is spiral.

There are two causes present, either of which may under favorable circumstances produce torsion:

*First*, the mechanical cell may be considered as a hollow cylinder whose walls are made up of material in layers of alternating density. In the diagram (*fig. 5*) let *fe* and *hg* represent dense layers of material while the less dense are the layers between. When dry, the cell is twisted with watch hands. Water enters first into the less dense layers forcing the micellæ in all directions. Two of these forces are principally concerned here. The one, *ab*, acting at right angles to the spiral plane of more dense material, may be resolved into its two components *ax* and *xb*. One of these acts tangentially and tends simply to increase the diameter of the cell; the other moves the spiral plane in such a way as to increase the angle it makes with the axis of the cell, producing, in the wall of the cell toward us, motion from right to left. The other force, *ac*, may be resolved into its components, *ay* and *cy*, the first of which again merely tends to increase the diameter of the cell, and the second, acting nearly parallel to the component *ax*, will strengthen it. In the opposite wall of the cell the same forces will be found to produce the same result, but when seen through the cell, the direction of motion will be just opposite to that in the wall on this side. There can be but one result from the action of such forces — the two forces on opposite sides of a cell, acting in opposite directions about its center, will produce torsion.

*Second*, the eccentric position of the cellulose-like material about the lumen of the cell throws the center of the more dense material to one side of its axis, so that the dry cell on imbibing water will curve

with the denser material on the concave side; at least this would ordinarily take place. But such a bend in one plane is changed to a twist whenever the proper forces are present. In the case before us, we have not only the proper forces to cause a twist but also to give the motion constancy of direction, *i. e.*, with watch hands. These forces are found in the spiral arrangement of the material. In this case we should expect a waving or serpentine bend rather than a close twist. The fact that many cells are found, after applying reagents, in all stages from a beginning bend in one plane to a wavy twist, leads to the conclusion that this is, perhaps, the principal force of torsion when the lumen is very eccentric.

It is probable that both these causes act in conjunction to produce the generally resulting perfect torsion. — L. MURBACH, *Central High School, Detroit, Mich.*

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## SOME NEW SPECIES OF WYOMING PLANTS.

**Silene Tetonensis.**— Stems several, somewhat cespitose from a multicipital caudex, 10–25$^{cm}$ high, 1–7-flowered: minutely pubescent throughout, glandular above and often throughout, the leaves often glabrous except on the margins: leaves connate at base and sheathing by somewhat scarious membranes, the petioles often sparsely ciliate; the radical long-petioled, linear or narrowly oblanceolate, 2–8$^{cm}$ long, 2–6$^{mm}$ wide; the cauline linear or the lowest pair narrowly oblanceolate: calyx obovoid, 7–10$^{mm}$ long, with 10 purplish nerves, these anastomosing somewhat near the summit, 5-toothed, the teeth rotund or rhomboid-triangular, obtuse with very broad membranous margins: petals 9–12$^{mm}$ long, greenish-white or rose-color, more or less exserted; the claw 3$^{mm}$ broad, spatulate, with the margins entire or bluntly toothed near the summit, not at all auricled, 3-nerved, the nerves branched and anastomosing in the limb; this 3$^{mm}$ long, as broad as the claw or generally a little narrower, with no lateral lobes, emarginate or cleft to the middle, the lobes entire and rounded, the appendages much broader than long and bluntly toothed: stamens nearly as long as the claws of the petals, the filaments glabrous; styles 3, 1$^{mm}$ long: carpophore very short.

Related to the western *S. Watsoni*, but is readily distinguished from that by its broader radical leaves and very different petals.

The type is no. 6521 from the high grassy slopes of the Teton mountains, August 16, 1899; also no. 6684 from Dunraven peak in the Yellowstone park, August 27.

**Heuchera saxicola.**— Scape, petioles, and inflorescence villous and viscid-glandular, the leaves sparsely so: leaves oval to rotund, truncate or subcordate at base, doubly and incisely crenate with obtusish teeth, 2–4$^{cm}$ long, on petioles 4–9$^{cm}$ long: scapes slender, 2–4$^{dm}$ high, with two diminutive bract-like leaves near the summit: spike simple, often interrupted below, 3–6$^{cm}$ long; bracts ovate in outline, acuminate, 3-cleft to nearly entire and rhomboid, very ciliate on the margin, frequently tinged with violet, 6–8$^{mm}$ long: calyx campanulate, about 7$^{mm}$ long, very pubescent and glandular, villous at base, divided to about the middle; the tube adnate to the ovaries for slightly over half its length; the lobes unequal in size, ovate or oval, obtuse, white and petaloid: petals wanting: filaments from triangular to subulate, 1$^{mm}$ or less in length: capsule ovoid: seeds oval, hispid, brown.

*H. saxicola* is a near relative of *H. ovalifolia* Nutt., to which it is apparently referred in the recent published *Catalogue of the Flora of Montana*, for a specimen, collected by Rydberg and Bessey in the Spanish basin, belongs to this species. Referring to the original description, we find that *H. ovalifolia* is "wholly destitute of villous hairs," a negative character which at once excludes the plant here described. *H. ovalifolia* is originally from the region of the Columbia river, and is quite fully described in Howell's *Flora of Northwest America*. As here characterized, it has lanceolate and laciniate bracts, while in ours they are ovate in outline and either rhomboid or 3-cleft. The calyx is also described as tubular and with lanceolate lobes. In *H. saxicola*, on the other hand, the calyx is rather campanulate and the lobes broader.

Type, no. 5687, Undine falls in Yellowstone park, July 6, 1899; also, no. 2822, Little goose creek cañon, July 17, 1896.

**Saxifraga cognata.**— Cespitose, the numerous short, erect stems (1–3$^{cm}$ long) forming dense cushions, the lower part of the stems covered with old leaves: leaves imbricated, oblong-linear to lanceolate, cuspidate, 5–10$^{mm}$ long, hispid ciliate on the margins, otherwise glabrous: flowering stems slender, about 1$^{dm}$ high, sparsely covered with short purple-tipped hairs, as also the pedicels of the flowers, bearing several linear oblong leaves, these 3–5$^{mm}$ long and naked on the margins, or nearly so: inflorescence cymose, 5–7-flowered, seldom 9: calyx divided two thirds to three fourths; the lobes ovate, obtuse, or acutish, indistinctly 3-nerved, somewhat less than 2$^{mm}$ long: petals

elliptic, 4–5$^{mm}$ long, white, tinged with yellow toward the base, the upper half with purple dots, 3-nerved, the lateral ones arising near the base and extending to near the apex: ovaries united their whole length, the slender, conical styles more or less divergent.

This includes all of the so-called *S. bronchialis* of the Rocky mountains, and perhaps also of the mountains of the Pacific states. *S. bronchialis*, which is originally from Siberia, is everywhere described as having lanceolate sepals and orange-dotted petals, while our plant has ovate sepals, and petals quite prominently dotted with purple.

No. 5551, from Golden gate in the Yellowstone park, June 28, 1899, may be taken as the type of this species.

**Ribes saximontanum.**—A low shrub; spreading stems about 6$^{dm}$ long, more or less bristly, with straw-colored and shreddy bark; infra-axillary spines three together, stout, 8–12$^{mm}$ long: leaves orbicular or broader, truncate at base, 3-lobed half way to the base, the two lateral lobes again somewhat 2-lobed, the lobes with obtuse or acutish teeth, very finely pubescent on both sides or glabrate, 6–20$^{mm}$ broad: flowers 1–3, axillary, about 1$^{cm}$ long: calyx cylindraceous, glabrous, white tinged with violet: the tube 2$^{mm}$ broad or less, 4$^{mm}$ long, villous within; the lobes oblong, minutely toothed at the rounded summit, slightly shorter than the tube: petals cuneate-spatulate, toothed at the broad summit, about 2$^{mm}$ long: stamens included, the anthers oblong and obtuse: style divided half way to the base, villous: berry globose, smooth, reddish-purple, 6–10$^{mm}$ in diameter.

An excellent species, quite different from its southern relative *R. leptanthum*, from which it is readily distinguished by its bristly stems, glabrous whitish calyx, and divided villous style. It is an inhabitant of high, open slopes.

Type. no. 5542. Golden gate in Yellowstone park, June 28, 1899; also no. 695, Garfield peak, July 29, 1894, by *Aven Nelson*.

**Rosa grosse-serrata.**—Much branched, 6–18$^{dm}$ high, with occasional short prickles (less than 5$^{mm}$ long) or wholly unarmed, the branches purple and somewhat glaucous; stipules usually broad, 12–20$^{mm}$ long, entire or minutely glandular-toothed, the free ends triangular ovate, acute, or acuminate, usually minutely resinous dotted and finely pubescent: leaves 5–7-foliolate; the leaflets nearly sessile, the terminal petiolulate, elliptic to narrowly and cuneately obvate, sharply and coarsely serrate for about two thirds their length, 2–4$^{cm}$ long, glabrous above, sparsely and very finely pubescent and minutely resinous dotted (under

a strong lens) beneath as also the rachis: flowers in clusters of two to four at the ends of the branches or solitary: sepals entire, linear-lanceolate, attenuated, the tips only slightly dilated, sparsely pubescent on the back and occasionally hispid-glandular along the margins; petals unknown; fruit globose, perfectly smooth, about $12^{mm}$ in diameter.

Apparently intermediate between *R. pisocarpa* and *R. Woodsii*. From the former it differs in its stouter branches, in the minutely resinous lower surfaces of the leaves, and in the larger and more coarsely toothed leaflets. From the latter one cannot so easily find characters by which to distinguish it, yet it is so different in appearance that its separation as a distinct species seems to be justifiable. The so-called *R. Woodsii* of the Rocky mountains is a much lower plant, and has leaflets only $2^{cm}$ long.

The following collections of this species are at hand: no 1101, Boulder creek, August 27, 1894; no. 6787 (type), Madison river in the Yellowstone park, August 30, 1899; both by *Aven Nelson*.

**Lupinus ramosus.**—Stems several from a woody caudex, $2–4^{dm}$ high, branched, with divaricate branches, these simple and terminating in short few-flowered racemes: stems and petioles with two kinds of pubescence, finely canescent and sparsely villous with spreading hairs: leaves 5–8-foliate, the lower half the length of the petioles, the upper equaling them; leaflets narrowly oblanceolate, obtuse to acute, usually mucronate, densely soft-silky on both sides, $2–4^{cm}$ long, $5–9^{mm}$ wide: racemes short-peduncled, $3–5^{cm}$ in length, in fruit a little longer: bracts ovate or lanceolate, about $2^{mm}$ long: flowers somewhat verticillate or scattered, about $1^{cm}$ long; pedicels $2–3^{mm}$ long, in fruit $5^{mm}$; calyx bracteolate, densely silky, as also the pedicels, the lower lip a little longer than the upper, which is slightly notched: vexillum very silky on the back, the central portion yellowish-white, otherwise pale blue or lilac; wings pale blue, slightly longer than the vexillum; keel light-colored, ciliate on the margin except at the very tip: pod silky, 3–5-seeded.

Characterized by its branching habit, short and few-flowered racemes, and the two kinds of pubescence.

The type, no. 6576, is from dry banks and benches on Snake river, Yellowstone park, August 20, 1899.

LUPINUS HUMICOLA **Tetonensis.**—Stems one or more from the same root, simple $3–6^{dm}$ high, including the racemes, 3–5-leaved; leaflets acute or obtuse and mucronate, glabrous on the upper surface or

sparsely strigose, 5–9$^{cm}$ long, 8–18$^{mm}$ wide: raceme 4–12$^{cm}$ long, mostly only 4–5$^{cm}$.

No. 6341, Teton mountains, August 16, 1899.

**Antennaria fusca.**— Loosely cespitose: stolons about 5$^{cm}$ long: stems slender, 12$^{cm}$ high or less: leaves canescent or tomentulose on both sides, the older ones becoming glabrous; the radical and those of the stolons spatulate, indistinctly mucronate, 15–22$^{mm}$ long; the cauline linear, 2–4$^{mm}$ wide, the lower somewhat broadened upwards and acute, the upper acuminate: heads 3–13, on short pedicels in close clusters or loosely corymbose, and the head or heads of the lowest pedicel, which is often 2–3$^{cm}$ long, usually overtopping the rest: involucres about 6$^{mm}$ high: bracts (pistillate) in about two series, the lower half bright green and sparsely woolly, the upper portion brown or greenish-brown, oblong, obtuse, more or less serrate.

In habit and general appearance the species here described would suggest *A. aprica* Greene, yet it is not even a very near ally of that. Its dark-colored bracts, slender stems, and the dull and light indument of the leaves easily separate it specifically from Professor Greene's species.

The type is no. 6356, growing on dry bottoms and in open woods on Lewis river, Yellowstone park, August 8, 1899.

**Antennaria oblancifolia.**— Cespitose: stolons very short: stems slender, 15$^{cm}$ high or less: radical leaves oblanceolate, those of the stolons narrowly so, acute, mucronate, about 2$^{cm}$ long, sparsely canescent to glabrous above, canescently tomentose below: cauline leaves linear or oblong-linear, the lower acute, the upper acuminate: heads 4–13, in close racemose or paniculate clusters: involucres (staminate) 4$^{mm}$ high, the herbaceous portion of the bracts sparsely woolly, the scarious portion oval, obtuse, brownish, or white.

This is near to *A. racemosa*, but it is so strikingly different from that in the size and outline of its leaves that it must stand as a distinct species.

It is represented by a single collection in which all the plants are staminate, secured on an open, once wooded slope, near Mammoth hot springs in he Yellowstone park, July 3, 1899, no. 5640.

**Gnaphalium thermale.**— Low, 1–2$^{dm}$ high, branched from the base, the stems more or less branched throughout or simple to near the summit: stems and leaves grayish woolly: radical leaves oblanceolate, about 35$^{mm}$ long, the cauline narrowly oblanceolate to linear, 1–3$^{cm}$ long: heads sessile in small glomerules terminating the branches:

involucres 4–5$^{mm}$ high: bracts dull white, from ovate in the outer to linear in the inner, obtuse or acutish, nearly all apiculate.

A northern ally of the Texan *G. Wrightii*.

Collected on the geyser formations of Norris geyser basin in the Yellowstone park, July 25, 1899, no. 6139.

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Laramie.

## SOME NEW NORTH AMERICAN MOSSES.

(WITH PLATE XI)

IN July 1898 the writer, in company with Mr. James Blake, made a vacation trip into northwestern Montana, during which we collected especially mosses and hepatics. The region visited is reached by the Great Northern railway, which we left at Belton, thirty miles east of Kalispell. Thence we made our way to the north end of lake McDonald, some twenty miles north, where we pitched our permanent camp. The region visited is especially interesting because of the several glaciers which nestle among the precipitous mountain peaks. We visited only one of these, Sperry glacier, at the base of which we found several European mosses heretofore not reported for the United States, as well as some new species closely related to certain alpine species of the old world. So far as determined the material collected includes 140 species of mosses and 20 species of hepatics. The publication of a full report is delayed for various reasons, and it is deemed desirable to publish here only the most important part of the report as far as prepared. A more detailed account of this region, botanically as well as geologically very interesting, may be found in the September number of *Bulletin* of the American Bureau of Geography.

**Dicranoweisia subcompacta** Card. et Thér., sp. nova.—Dense pulvinato-caespitosa. Caulis simplex vel parcissime ramosus, 6–8$^{mm}$ altus, dense foliosus. Folia madida suberecta, sicca crispatula, 1–1.5$^{mm}$ longa, oblongo-lanceolata, acuminata, subacuta vel obtusiuscula, superne, canaliculata, nervo basi attenuato usque ad apicem producto vel paululum infra evanido, marginibus inferne planis, superne inflexis, integerrimis, cellulis irregulariter quadratis vel subrectangularibus, inferioribus laxioribus, juxta costam linearibus, alaribus distinctis, subinflatis, fuscis. Caetera ignota.— *Plate XI.*

Very nearly allied to the European *D. compacta* Sch., from which it differs by the leaves being more narrowly acuminate and generally subacute, the cells of the areolation larger and with thinner walls, and chiefly by the costa narrower, attenuate below (16 to 25$\mu$ broad; it is 55$\mu$ in *D. compacta*).— Along the trail from Holzinger's basin to the Rim.

**Barbula rufipila** Card. et Thér., sp. nova.— *B. aciphyllae* habitu et foliorum forma omnino similis, differt tantum cellulis duplo majoribus et magis distinctis (superioribus 20–30$\mu$ in *B. rufipila*, 12–15$\mu$ in *B. aciphylla*) piloque saepius minus denticulata interdum integro. Specimina sterilia.— *Plate XI.*

Avalanche basin; Holzinger's basin.

FISSIDENS BRYOIDES GYMNANDRUS (Buse) R. Ruthe.— New to North America. Cardot det.— Shores of lake McDonald; Avalanche trail.

**Grimmia Holzingeri** Card. et Thér., sp. nova.— Minima, tenella, pulvinatula, obscure viridis, inferne fusca. Caulis erectus, 4–6$^{mm}$ altus, parce ramosus, ramis interdum attenuatis, subflagellaceis. Folia conferta, minima, 0.50–0.70$^{mm}$ longa, 0.20–0.35 lata, madida erecta, sicca appressa, breviter ovato-oblonga, concava, omnia mutica obtuse acuminata, marginibus planis integris, costa canaliculata, usque ad apicem producta, basi 28$\mu$ lata, cellulis superioribus bistratosis, quadrato-subrotundatis, inferioribus unistratosis majoribus, lutescentibus, infimis oblongis vel sublinearibus, omnibus incrassatis. Caetera ignota.— *Plate XI.*

This very minute species, resembling in habit the small forms of *Andreæa petrophila*, is quite distinct from all the European and North American species of Grimmia with muticous leaves by the small size, and the shape and areolation of the leaves.— Base of Sperry glacier; Mt. Trilby.

GRIMMIA MOLLIS B.S.— This European alpine moss is reported from Greenland, and should be found at intermediate stations in Canada.— Base of Sperry glacier.

GRIMMIA SUBSULCATA Limpr. in Rabenh. Cryptog. Fl., Laubm. 757.— New to North America. Cardot det.— Mt. Trilby.

WEBERA CARINATA (Brid.). (*W. cucullata carinata* Husnot; *Bryum naviculare* Cardot).— New to North America. Cardot det.— Base of Sperry glacier.

BRYUM ALPINUM L., var. **denticulatum** Card. et Thér., n. var.— A forma typica differt habitu graciliore, foliis ovato-acuminatis,

brevioribus, marginibus parum revolutis, superne distincte sinuato-denticulatis, costaque longe ab apice dissoluta.—On the way from Holzinger's basin to the Rim.

PSEUDOLESKEA RADICOSA (Müll.) Lesq. & James.—This species was distributed as *P. rigescens* Lindb.: it is the *P. atrovirens* of European authors. Best det.—Holzinger's basin; Mt. Trilby.

PSEUDOLESKEA DENUDATA HOLZINGERI Best, in Bull. Torr. Bot. Club **27**: 229. May 1900.—Holzinger's basin; Mt. Trilby; Avalanche basin.

**Hypnum Cardoti** Thér., sp. nova.—Polygamum, olivaceo-viride, molle, laxiuscule depresso-caespitosum. Caulis procumbens vel ascendens, irregulariter ramosus, 2–4$^{cm}$ longus. Folia remotiuscula, patulo-squarrosa, interdum subsecunda, e basi constricta anguste decurrente late ovato-deltoidea, subito in acumen angustum breviusculum recurvum protracta, circa 1.5$^{mm}$ longa et 0.75 lata, marginibus planis fere undique sinuato-denticulatis, costa simplici bifurcata vel gemella, crure longiore ad medium producto, cellulis laxiusculis linearibus subflexuosis, basilaribus brevioribus et latioribus, alaribus laxis majoribus subhyalinis. Folia perichaetialia externa ovato-lanceolata, breviter acuminata, subintegra, enervia, intima plicata, costata. Capsula in pedicello rubente valde flexuoso, circa 18$^{mm}$ longo, subhorizontalis, arcuata, operculo convexo apiculato.— *Plate XI.*

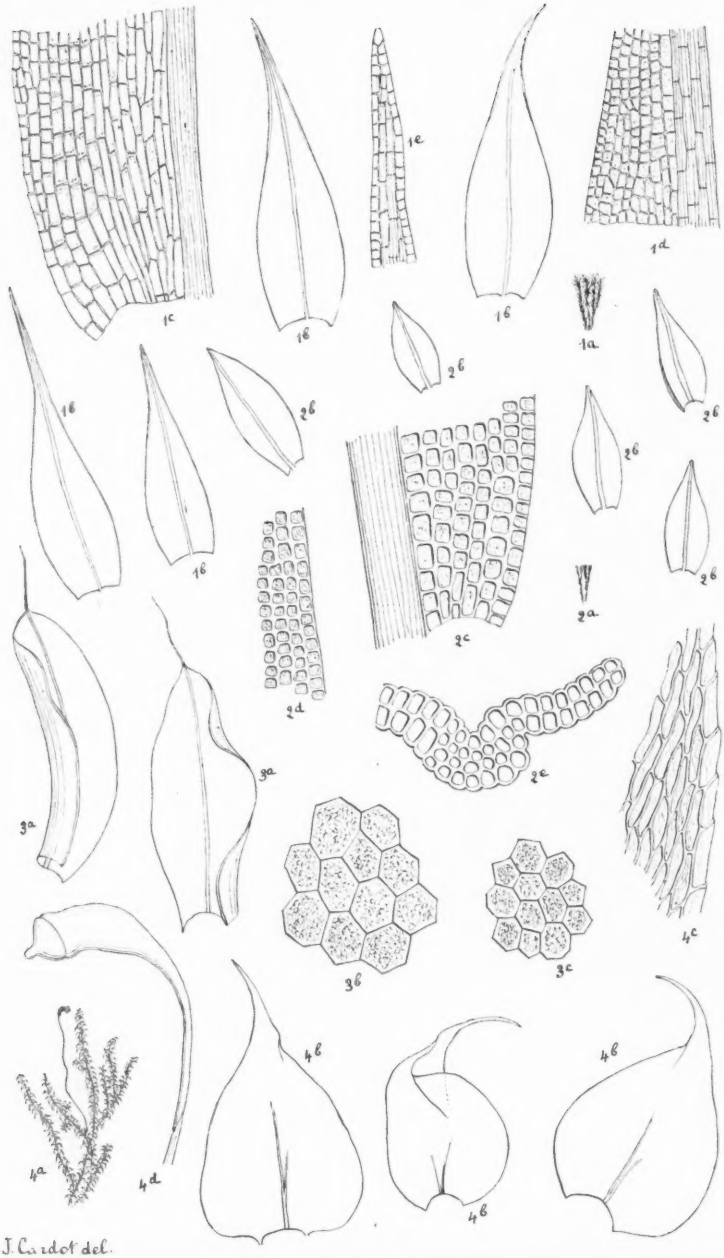
This species is near *H. stellatum* Schreb. and *H. polygamum* Sch. From the first it is at once distinguished by the polygamous inflorescence and the softer leaves with a shorter acumen and a looser areolation. The shape of the stem leaves and of the perichaetial leaves distinguishes it from the small forms of the second species.—Avalanche basin.

HYPNUM FLUITANS L., var. BRACHYDICTYON Ren. in Husnot Musc. Gall., forma **Holzingeri** Ren.—Voisin de la var. *brachydictyon* Renauld, n'en diffère que par le port plus grèle, la nervure plus étroite, et le tissu délicat. Dioique ♀!

Cette var., essentiellement alpine, n'avait pas encore, je crois, été signalée en Amérique.

A cause de la brièveté des cellules médianes, on pourrait confondre cette forme avec *Hypnum aduncum* Hedw.; mais le passage brusque des cellules foliaires de la base aux cellules superficielles de la tige permet d' éviter la confusion.—Base of Sperry glacier.

HYPNUM OCHRACEUM UNCINATUM Milde.—A European alpine moss, new to North America. Renauld det. Holzinger's basin.




J. Cardot del.

HOLZINGER on MOSSES

HYPNUM UNCINATUM Hedw., var. SUBJULACEUM Sch., forma **Holzingeri** Ren.— Forme voisine de la forme *orthothecioides* Lindb.; en diffère par la couleur verte, les touffes compactes encombrées de terre à la base, l'acumen plus court denticulé et le tissu plus délicat, non épaissé.— Base of Sperry glacier.

Minor extensions of range will be noted in a fuller report on this collection.— JOHN M. HOLZINGER, *Winona, Minn.*

## EXPLANATION OF PLATE XI.

(Nachet's objectives 3 and 6, oculars 1 and 3, with camera lucida. All drawings are reduced ¼ in photo-engraving.)

1. *Dicranoweisia subcompacta.* *a*, entire plant, nat. size; *b*, *b*, *b*, *b*, leaves, × 32; *c*, basal areolation × 135; *d*, marginal areolation in the middle × 135; *e*, point of a leaf × 135.

2. *Grimmia Holzingeri.* *a*, entire plant, nat. size; *b*, *b*, *b*, *b*, *b*, leaves × 32; *c*, basal areolation × 285; *d*, marginal areolation in the middle × 285; *e*, transverse section of a leaf × 285.

3. *Barbula rufipila.* *a*, *a*, leaves × 13; *b*, areolation in the upper part × 285: *c*, the same of *B. aciphylla* from a specimen of Styria × 285.

4. *Hypnum Cardoti.* *a*, entire plant, nat. size; *b*, *b*, *b*, leaves × 32; *c*, marginal areolation in the middle × 285; *d*, capsule × 13.

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## NOTES OF TRAVEL. III.

### RIO AND PETROPOLIS, BRAZIL.

TO A professional traveler and to a botanist Rio de Janeiro and Petropolis have more to offer than any other easily accessible place in South America. Mr. Barbour Lathrop, with whom the writer has the pleasure of traveling as assistant, is familiar with many of the picturesque spots in the world, and even to him the region about Rio was a most agreeable surprise.

We visited together in 1897 the harbor of Sydney, Australia, which is most commonly compared with that of Rio, and were able to draw comparisons which are decidedly favorable to Rio.

Sydney harbor is long and, in comparison with that of Rio, narrow, with a great number of small coves separated by sharp points of land which jut out into the stream. These points of land, each side of the harbor, alternate with the coves opposite, like the teeth of a shark. These low and rounded hilly points are covered with Australian

scrub, which is composed of narrow-leaved acacias, eucalyptus, and numerous Myrtaceæ of a gray-green color. To those who tire of the gray-green of Italian olive groves, these narrow-leaved Myrtaceæ soon become monotonous, and the scanty shade shed by the sickle-shaped vertical leaves of the eucalyptus makes little in the landscape that is restful to the eye. There are scarcely any islands in Sydney harbor, and its principal charm to a traveler lies in these innumerable coves which on either hand pop into view from the steamer. They are often filled with shipping, and the shores are being rapidly denuded of their forest and scrub vegetation, though many quiet pretty views still remain. A botanist finds in the curious Proteaceæ, the most peculiar grass trees (*Xanthorrhoea*), and the endless variety of Myrtaceæ a host of forms which tickle his morphological sense with their novelty.

Rio harbor, on the other hand, is like a large inland lake, with numerous islands scattered through it, and surrounded by tall curiously rounded sugar-loaf hills. Islands, hills, and low-lying swampy shores are covered with a wealth of tropical vegetation quite as luxuriant as any to be seen directly under the equator. In place of the rounded gray-green of the hills of Sydney, Rio has dark imposing cliffs which reach above the low-lying clouds. Their deep ravines and valleys are a tangle of creepers, bright purple flowered melastomas, broad-leaved lilies, and innumerable epiphytic bromelias. Everything is steaming with moisture and the leaf tips are dripping with dew.

The islands in the harbor, though very picturesque, lack both cocoanut palms and coral reefs, two features which give to the islands of the south seas their peculiar charm. The former lack could easily be remedied, but the brilliant white coral reef would be difficult to supply.

Rio is the most picturesque city in South America. The Portuguese architecture is a great relief after the monotony of Spanish American cities, and no suburb in any city that I know is more charming than Botafogo, the residence portion of Rio. Each picturesque house, of yellow or pink stucco, trimmed with colored Moorish tiles and roofed with red tiling, is set in a half-neglected garden of tangled flowering creepers, bamboos, ficus trees, and foliage plants. Although not as well taken care of as the American gardens of Honolulu, they are much more numerous and picturesque. In fact, I do not believe there is a place in the world where such an array of picturesque gardens and houses can be seen as here in Rio.

The characteristic feature of Rio vegetation is made by the avenues of royal palms. Although there are avenues of this palm in Java, Hawaii, Jamaica, Trinidad, and Ceylon, in none are they really impressive. The first leaf-sheath in young plants is always objectionably prominent. The immense avenues of Rio are so tall that these leaf-sheaths are not noticeable. No more beautiful avenues of palms are imaginable than those of the Botanic Gardens and a double avenue near Botafogo.

The Botanic Garden lies an hour's train ride from the center of the city, in a locality unfortunately infested with yellow fever. Its most courteous director, Dr. Rodrigues, has made a special study of palms, and his collections are very tastefully arranged through the garden. Although containing many rare specimens, this collection does not compare in any respect with that in the gardens of Java or Ceylon. Owing to its situation so far from comfortable hotels and its lack of laboratory facilities, the garden will be a difficult place in which to prosecute botanical studies. In the winter months the danger from yellow fever would quite prohibit its being used except for a few hours a day, as no stranger who values his life risks living in the city, but spends his nights at least either at Petropolis, three and one half hours away, or at Tijuaca, much nearer, but not so free from fever.

The charm of Rio, botanically, is in its surroundings. Petropolis, a city of twenty thousand inhabitants, lies at an altitude of three thousand feet among the mountains across the bay from Rio, and is reached by two hours of ferryboat and railway travel. During the season of yellow fever, from January to June, over two hundred passengers, mostly business men, make this trip twice a day, leaving Petropolis every morning and returning in the evening. As the danger from yellow fever is only incurred by exposure to the night air, Europeans live in perfect security by making their homes in Petropolis and never spending a night in Rio during its summer season.

The ride to Petropolis is richer in panoramic effect than any road of like length in the tropics, surpassing the famous railway journeys from La Guayra to Caracas in Venezuela, Columbo to Kandy in Ceylon, and from Padang to Padang Pandjang in west Sumatra. The vegetation near the shore of the harbor, through which the railway passes, resembles that of the dense swamps characteristic of the isthmus of Panama—a paradise for the collector of fresh water algæ, but infested with malaria. These low lands are covered with a tangled

jungle of ferns, convolvulus, bananas, and flowering lilies, enlivened by occasional characteristic melastomas, one blaze of dark purple flowers. As the train climbs the steep incline and the cogs of the miniature engine grasp the cog rail a panorama of increasing grandeur is unrolled. It comprises the whole harbor with its dark green islands and surrounding densely forest-clad mountains. Dark green cliffs, covered everywhere with masses of creeping plants, tower above the train, their tops concealed by low-lying clouds. At one point a deep narrow valley spreads out into the plain below and from the train one looks down upon square miles of tropical tree tops of various shades of green.

The evidences of intense insolation in the deep reds and bright yellows of the young foliage are few as compared with west Java, Sumatra, or Trinidad, and the occasional white foliage of a species of Araliaceæ remind one of the candle nut trees (*Aleurites*) in the Hawaiian landscapes. In the early morning a sea of clouds shuts out the view of the harbor and replaces it with a most curiously effective scene.

Rio is the largest city of Europeans within the tropics, and upon Petropolis, its fashionable suburb, has been expended, in beautiful villas and gardens, the wealth and taste of its most successful merchants. The climate is that delightful one characteristic of the high altitudes in this latitude. Cool, even cold, nights and bright warm days mark the winter, with occasional cloudy weather and frequent showers. In summer there is almost perpetual, sometimes uncomfortably warm, sunshine but with always cool nights. During our stay in May, corresponding to our autumn, the nights were cold, the mornings crisp and cool, and midday was never uncomfortably warm.

The forests immediately surrounding Petropolis are a second growth. Within easy walking distance, however, there are large stretches of virgin forest, with jungles in which climbing bamboos, tree ferns, purple flowering melastomas, begonias, occasional epiphytic orchids and phyllocactus, and an abundance of bromelias and lianas make up the undergrowth between the immense forest trees of Myrtaceæ and Ficus. The roadsides are lined with thickets of native raspberries, bearing attractive bright red but insipid fruit. The walls of the embankments are covered with mosses, filmy ferns, lichens, and liverworts, with occasional polypodium. The light gray trunks of the forest trees are spotted with bright red patches formed by a species of

lichen, and the branches of the trees are thick with fern, bromelia, and moss epiphytes, characteristic of moist tropical mountains. The sunny clearings in these forests are simply alive with brilliant butterflies, and here and there across the paths are files of the leaf cutting *Atta* ants, which Belt and Möller have so well described. Patches of Cuphæa by the roadside are especially subject to the attacks of these interesting leaf cutters, and their intelligent movements as they cut and carry the leaves and tender stems to their nests are perfectly fascinating and worthy a much more serious study than has so far been given them. Beaten paths cleared of all dead leaves and fragments of stone can be traced for many yards through the forest, leading to the openings of the nests, down which in endless streams the busy cutters tumble leaf fragments, which they have brought balanced between the spines of their thoraci.

A few inches beneath the surface of the ground these leaf fragments are masticated and molded into the sponge-like mushroom-bed upon which the fungus grows that forms the "*kohl rabi*," which is the necessary food of the species. A one sided warfare is waged against these attas by a powerful species of black ant, over half an inch long, and my friend and I watched with keen interest the slaughter of a dozen or so of the leaf cutting workers by a single one of these assassins, who killed every individual he found, as a terrier would a rat.

Although there are no laboratory facilities of any kind in Petropolis, its natural advantages for a botanist are exceptional. Proximity to the virgin forests, a climate in which one can work as comfortably as in New England, the most beautiful scenery imaginable, and a large and highly intellectual society of Europeans, make it a place without equal in the mountains of the tropics. Living in the hotels *en pension* would amount to about $2 a day for all expenses. A bicycle could be used to excellent advantage in making excursions along the country roads, which are very good in the neighborhood of the town. Excursions to Cascatina, Itymarati, and the Organ mountains are full of the liveliest interest, and an abundance or material for morphological and biological studies can be easily gathered together.

The Corcovado is a tall mountain overlooking Rio, from which a view of unparalleled interest is obtainable and Tijuaca is a small village lying in the cul de sac between the hills behind it. The latter is surrounded by dense forests, which are penetrated by many miles of well kept wagon road, forming doubtless the most extensive natural

park of its kind in the tropics. Rio being the railway center of Brazil, excursions to the interior are made with comparative ease.

To any botanist who wishes to study tropical vegetation, and who has at the same time an eye for the beautiful, Petropolis and the other suburbs of Rio will prove beyond question the most attractive place in the world. As compared with the mountains of Java or Sumatra they are civilized, have a much more salubrious climate, and all the conveniences of modern civilized life. The south island of Hawaii or the south Pacific islands have no such stretches of virgin forest, nor such a flora or fauna to explore. Ceylon is hot and uncomfortable in comparison, and the mountains of Jamaica and Trinidad are uninhabited except by scattered planters.

It is the writer's belief that there is no other place in the world where such a combination of tropical vegetation, wonderful scenery, civilization, and cool equable climate can be found.—D. G. FAIRCHILD, *Port Said, Egypt*, September 21, 1899.

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## ANOTHER NOTE ON THE FLOWER VISITS OF OLIGOTROPIC BEES.

SINCE the table in the BOTANICAL GAZETTE **28**: 36 was published, *Andrena arabis* has been found collecting pollen of *Cardamine rhomboidea*. In the second column, therefore, Cruciferæ should be substituted for *Arabis laevigata*.

Of the three species of Calliopsis enumerated on page 28 of the same volume, one, *C. andreniformis*, is quite polytropic. Another, *C. coloradensis*, I think, is oligotropic and gets its pollen exclusively from Compositae. It collects pollen of *Boltonia asteroides* and *Coreopsis aristosa*.

A male of the third species was taken on August 23, 1897, on flowers of *Verbena stricta*. I did not care to describe it until I had found the female. July 15, 1899, the sexes were taken in copula on flowers of *Verbena urticifolia*, the females collecting the pollen. The males were also taken on *V. hastata*. In the mean time, the bee was taken in New Mexico on flowers of *V. macdougalii* by Miss Porter, and was described by Cockerell under the name of *Calliopsis verbenae*. This author says nothing about it collecting the pollen. The bee is evidently an oligotropic visitor of Verbena.—CHARLES ROBERTSON, *Carlinville, Illinois*.

# CURRENT LITERATURE.

## BOOK REVIEWS.

### A practical garden book.

THE LATEST of the Garden Craft Series is a compact little book of 250 pages for amateur gardeners,[1] in which the subjects are arranged in cyclopedic fashion. This alphabetic arrangement is supposed to make unnecessary both table of contents and index, but the latter would have been useful for cross references.

The range of subjects treated is wide, as may be seen by the following, taken at random from "C": Cucumbers, Currants, Cuttings, Cutworms. A section from "F" reads as follows: Ferns, Fertilizers, Feverfew, Fig, Flowerbeds.

The aim has been to afford information on simple garden operations in the simplest possible form. The effort, so far as it has been carried out, has been fairly successful, and as a rule little fault can be found with the quality of the advice given, although under "Dahlia" the direction given to "place the roots in gentle heat" might easily lead the amateur into difficulties unless he is familiar with technical terms.

The information is mainly of local application, being adapted to central and northern latitudes. The book may prove of some value as a reference book to persons entirely ignorant of gardening operations in much the same way as an alphabetical list of common French or German phrases would be of value to the traveler in Europe.

*Garden making*, an earlier book of this series, is greatly superior, as it covers a wider field and treats in plain language the principles of the art of gardening, something absolutely essential for the beginner. It is extremely doubtful if a beginner, in consulting the present volume, would look up soils, cultivation, fertilizers, etc., before sowing his seeds. As a companion, possibly as a complement to *Garden making*, it will be useful to those who can buy many books, but, taken by itself as a garden guide, it is of comparatively little value. Indeed its publication leads one to suspect an effort to unload on the public a new book simply for the purpose of gain; an effort of publishers too often attempted and commonly successful. And Professor Bailey's name seems to be attached to this volume merely as a makeweight for this purpose. —F. W. CRANEFIELD.

[1] HUNN, C. E., and BAILEY, L. H.: Amateurs practical garden book, containing the simplest directions for the growing of the commonest things about the house and garden. Pp. vi + 250. Illustrated. New York: The Macmillan Company. 1900. $1.00.

**Three popular books.**

POPULAR interest in plants is being cultivated recently by numerous books of high artistic merit and variable scientific quality. Several of them have been noticed in this journal, and three others now deserve attention, all of which stand high in their class. To interest the public in making intelligent observations is a most commendable purpose, but the temptation to arouse interest by bringing together doubtful facts and legends is very strong, and the effect is sometimes more than doubtful.

*Nature's garden*[2] is the title selected by Neltje Blanchan (a *nom de plume*, we understand, of Mrs. Doubleday). The book considers flowers from the standpoint of pollination by insects, and the best authors seem to have been consulted. Over five hundred flowers are represented, and are grouped according to color, "because it is believed that the novice, with no knowledge of botany whatever, can most readily identify the specimen found afield by this method, which has the added advantage of being the simpler one adopted by the higher insects ages before books were written." The classification by colors is as follows: blue to purple flowers, magenta to pink flowers, white and greenish flowers, yellow and orange flowers, red and indefinites. The book is on a higher plane than those which merely seek to lead the observer to a name, for the name is only an introduction to some real acquaintance. The illustrations deserve special commendation, for the half tones from photographs and the colored photographs made direct from nature are of exceptional merit. The former bring out details with that exquisite clearness which good photographs can obtain, while the latter represent the best results of color photography, which we must confess is frequently uncertain as yet as to shades. The book appeals to those interested in beautiful illustration, to those desiring a better acquaintance with flowering plants, and to those who are seeking on every hand help in organizing nature study.

ALICE LOUNSBERRY, the author of *A guide to the wild flowers*, has published a companion volume entitled *A guide to the trees*,[3] which well sustains the reputation of the former. Nearly two hundred trees are represented, and among them are all those prominent in northeastern America. There is every effort to make determinations easy, by using comparatively few technical terms and by employing the most obvious characters. For example, the

[2] BLANCHAN, NELTJE: Nature's garden, an aid to knowledge of our wild flowers and their insect visitors, with colored plates and many other illustrations photographed directly from nature by Henry Troth and A. R. Dugmore. Large 8vo. pp. xvi + 415. New York: Doubleday, Page & Co. 1900. $3.00.

[3] LOUNSBERRY, ALICE: A guide to the trees, with 64 colored and 164 black-and-white plates and 55 diagrams by Mrs. Ellis Rowan, with an introduction by Dr. N. L. Britton. 8vo. pp. xx + 313. New York: Frederick A. Stokes Company. 1900. $2.50.

primary classification is on the basis of soil, as follows: trees preferring to grow near water (in swamps and by running streams); trees preferring to grow in moist soil (lowlands and meadows); trees preferring to grow in rich soil (forests and thickets); trees preferring to grow in sandy or rocky soil (hillsides and barrens); trees preferring to grow in light or dry soil (upland places, meadows, and roadsides). The arrangement within these five sections is on the basis of leaf characters. The illustrations in color are from originals painted by Mrs. Rowan, and are both artistic and accurate. The pen-and-ink sketches are not so well done, but they are very helpful in determinations.

In the technical description of trees, and in what may be styled the literary appendix to each, the author is on safe ground; but in the pages on "the growth of trees" the statements become ancient in form, vague, and sometimes erroneous. The meaning can be caught by one familiar with the subject, but to the untrained the explanations do not explain.

HARRIET L. KEELER has also written a most attractive book on trees.[4] It is designed to enable the amateur botanist and the general public to recognize trees and so become interested in them. The book is straightforward and matter-of-fact, and is calculated to develop a rational rather than a sentimental or literary interest in trees. The descriptions are clear and simple, and the accompanying remarks in the main have to do with range, time of blooming, general appearance, notable habits, uses, etc. The illustrations from photographs are as perfect as any we have seen, being exceptionally fine examples of photography and half-tone reproduction. Every detail stands out with the distinctness of the original specimens. The same high commendation cannot be given to the drawings and their reproduction, which are in sharp contrast with the exquisite half tones. As in all such books, one finds a venerable and profuse terminology, which has largely outlived its usefulness.

These books can be commended to the general public and to teachers seeking for suggestions of interesting material.—J. M. C.

## MINOR NOTICES.

FASCICLES 195, 196, and 197 of Engler and Prantl's *Die natürlichen Pflanzenfamilien* have recently appeared. The first contains the completion of the Salviniaceæ and the Marsiliaceæ by R. Sadebeck and the beginning of the Marattiaceæ by G. Bitter. Fascicles 196 and 197, a double number, contain the Sphaeropsidales, Melanconiales, and Hyphomycetes, by G. Lindau.

[4] KEELER, HARRIET L.: Our native trees, and how to identify them; a popular study of their habits and their peculiarities, with 178 illustrations from photographs and 162 illustrations from drawings. 8vo. pp. xxii + 533. New York: Charles Scribner's Sons. 1900. $2.00.

## NOTES FOR STUDENTS.

IN A SOMEWHAT extended paper on geotropism[5] Dr. F. Noll controverts with much vigor Czapek's theory of geotropism, as expounded recently.[6] Czapek holds that since gravity and centrifugal force act alike upon plants this can only be because both impart mass acceleration, and this can manifest itself only in pressure of tissue elements or even layers of tissue upon one another. Thus there will be minute differences of radial pressure on different sides of the cortex which must be perceived and responded to by the growing cells. Orthotropic organs seek to equalize such pressures on the flanks; plagiotropic organs (dorsiventral or radial) seek to realize a certain difference of pressure to which they are attuned. To support this view he appeals to the elimination of geotropic effects by the clinostat under proper conditions, and to the behavior of dorsiventral organs both flat and rolled or folded. To this theory Noll strenuously objects. He concludes that the clinostat does not eliminate geotropic stimulation, but only converts the one-sided stimulus of gravity into an all-sided intermittent one. In radial organs rotation prevents curvature, but not in dorsiventral organs, which, even on the clinostat, show geotropic (pseudo-epinastic) curvatures.

Experiments on various organs, ingeniously subjected to artificial radial pressure equal to that of gravity, resulted negatively. Furthermore the behavior of twiners is cited to show that gravity acting tangentially produces acceleration of growth as well as when acting radially. Turning to dorsiventral organs, Noll urges that mere rolling or folding does not suffice to produce orthotropism, but that this is a true geotropic response. He cites physiologically dorsiventral but anatomically radial organs, such as the peduncles of Tropæolum, Linaria, etc., which with age reverse their anatomical structure, to show that the coarser cell structure has nothing to do with geotropic sensitiveness.

A few years ago Czapek discovered that geotropically stimulated roots treated with reducing reagents react differently from unstimulated ones.[7] In his later paper (*l. c.*) he declares that this "makes objectively visible the process of perception." To this Noll objects as going too far; the chemical phenomena are rather secondary and are not closely connected with the perception of the stimulus.

At the close of his paper Noll suggests a possible structure for the receptive apparatus, which must be located in the ectoplasm in order to have the necessary fixed orientation. The plasma has a tendency to form globular centrosphere-like bodies and the receptive apparatus may well be analogous

[5] NOLL, F.: Ueber Geotropismus. Jahrb. f. wiss. Bot. **34**: 457–506. 1900.

[6] CZAPEK, FRIEDRICH: Weitere Beiträge zur Kenntniss der geotropischen Reizbewegungen. Jahrb. f. wiss. Bot. **32**: 175–308. 1898.

[7] Berichte d. deutsch. bot. Gesells. **15**: 516. 1897.

to the otocyst of some lower animals, and have the form of a centrosphere containing a centrosome of different specific gravity from the liquid in which it lies, the wall being locally sensitive to the pressure of the centrosome and functionally connected with the release of action in the growing zone. Such an organ need not be of visible size, and it is unlikely that it is the already known centrosphere connected with cell division.—C. R. B.

ITEMS OF TAXONOMIC interest are as follows: C. L. SHEAR (Bulletin 23, Division of Agrostology, Dept. of Agric.) has published a revision of the N. Am. species of *Bromus* occurring north of Mexico, recognizing 36 species and 28 varieties, 45 of which are native and 19 introduced, and describing 15 new varieties, 3 new species, and a new subgenus (*Neobromus*).—R. E. SCHUH (Rhodora **2**:111–112. *pl. 18*. 1900) has described a new genus of brown algæ, calling it *Rhadinocladia*.—T. F. ALLEN (Bull. Torr. Bot. Club **27**: 299–304. *pls. 10–15*. 1900) has described three new charas from California.—L. F. HENDERSON (*ibid.* 342–359) has described 26 new plants from Idaho and other northwestern localities.—R. CHODAT (Mém. de l'Herb. Boiss. 17:10. 1900) has described three new genera of Protococcoideæ from the plankton flora of the ponds of Denmark, naming them *Lemmermannia*, *Hofmania*, and *Catena*.—F. STEPHANI (*ibid.* 16:1–46. 1900), in continuing his *Species Hepaticarum*, presents *Calycularia* (6 spp.), *Makinoa* (1 sp.), *Cavicularia* (1 sp.), *Blasia* (1 sp.), *Pellia* (3 spp.), *Androcryphia* (1 sp.), *Petalophyllum* (2 spp.), *Treubia* (2 spp.), *Fossombronia* (40 spp.), *Haplomitrium* (1 sp.), and *Calobryum* (3 spp.)—W. N. SUKSDORF (Deutsch. bot. Monats. **18**: 86–88. 1900), in continuing the publication of Washington plants, describes new species or varieties in the following genera: *Ribes*, *Epilobium*, *Boisduvalia*, *Godetia*.—JAMES BRITTEN and E. G. BAKER (Jour. Bot. **38**: 241–246. *pl. 411*. 1900) have published some notes on *Eryngium*, with special reference to certain obscure North American species.—J. W. CONGDON (Erythea **7**:183–189. 1900) has published a fascicle of new species from Mariposa co., Cal., representing the genera *Sidalcea*, *Ribes*, *Epilobium*, *Echinocystis*, *Selinum*, *Erigeron*, *Wyethia*, *Cnicus*, *Gilia*, *Collinsia*, *Mimulus*, *Castilleia*, and *Orthocarpus*.—A. ENGLER (Bot. Jahrb. **28**: 291–384. 1900), in continuing his *Beiträge zur Flora von Afrika*, presents the following contributions: M. GÜRKE on Verbenaceæ (II), Borraginaceæ (I), and Labiatae (V); P. HENNINGS on the fungi of eastern Africa; K. SCHUMANN on a new family of Malvales, which he calls *Triplochitonaceæ*, the single genus being *Triplochiton*; A. ENGLER and numerous collaborators on a collection from the lake Nyassa region, abounding in new species.—G. HIERONYMUS (*ibid.* **29**: 1–35. 1900) has published an account of the Compositae of Ecuador, 270 species being enumerated, many of which are new.—TH. LOESENER (*ibid.* 86–106) has published a second paper on the flora of Central America.—KARL REICHE (*ibid.* 107–119) has published a revision of the South American

family Calyceraceæ.— P. GRAEBNER (*ibid.* 120) has published a revision of *Linnaea*, including *Abelia* under it as a subgenus, the genus thus containing 26 species, 12 of which are new.—The most recent "Contribution from the Gray Herbarium" is by M. L. FERNALD (*Proc. Am. Acad.* **35**: 489–573. June 1900). It contains a synopsis of the Mexican and Central American species of the great genus *Salvia*, 209 species being recognized, 57 of which are new; a much needed revision of the Mexican and Central American species of *Solanum* § *Tovaria*, 10 species being presented, four of them new; and some undescribed Mexican seed-plants, 31 in number, chiefly Labiatae and Solanaceæ.—J. M. C.

A NEW THEORY of myrmecophily is proposed by Buscalioni and Huber.[8] Writing from Pará, Brazil, last September, they say that Schimper's attractive theory, that the symbiosis exists on account of the plant's need of protection against leaf cutting ants, not only fails to account for the facts, but is directly contrary to many. They find myrmecophilous plants restricted to regions subject to present or recent inundation, which points to a connection between this condition and the development of myrmecophily. This connection appears simple: when the low regions were overflowed the ants were compelled to take refuge on the trees and shrubs, and naturally sought out the hollow parts in which to stow away their larvae. The fodder provided for the police-like guests is probably to be ascribed to the direct influence of the ants themselves or of the Aphides or Coccidæ which seek it. As the regions remoter from the streams became less subject to overflow the ants may have retained their dwellings, although the need had passed, while the protection to the plants may have given the latter an advantage over competitors.

The authors state certain consequences of their theory, which so far have proved true:

1) If a plant genus consisting of some ant-free and some myrmecophilous species has different species in the upland and in the inundated land, as a rule the upland forms will be free of ants, and only those in the inundated region will be myrmecophilous.

2) Those myrmecophilous species which occur on dry land may be derived either from those which occur in inundated localities or they are found in localities which were periodically overflowed in earlier times.

3) The myrmecophilous plants of deeply inundated regions are mainly trees; those in regions of shallow overflow are shrubs.

The authors promise the publication shortly of thorough investigations on the biology and anatomy of the ant plants.—C. R. B.

IN HIS RESEARCH on rheotropism of roots Juel used a neat device for obtaining a current of water of uniform rate to impinge upon roots under

[8] Beihefte zum Bot. Centralbl. **9**: 85–88. 1900.

experiment.[9] To a central disk on the end of a vertical rod are attached six radiating arms of strong brass wire, on which are slipped cork disks, and to them seedlings are fastened in any desired position. This carrier is supported above a circular dish of water into which the roots depend while it is rotated on a clinostat. To prevent the retardation of the water as much as possible three other glass vessels each about $6^{cm}$ less in diameter than the next outer one are cemented to it, thus dividing the water chamber into three concentric spaces $3^{cm}$ wide, in which the rate of movement was practically unaffected by the retarding action of the immersed rootlets.

For rheotropic curvatures roots of *Vicia sativa* ($2–3^{cm}$ long) and maize ($3–4^{cm}$ long) proved best adapted. Currents varying from $0.8^{m}$ per second (using a hot air motor) to $0.3^{mm}$ per second were tried. The lower limit of sensitiveness was not reached even at the lowest speed. Curvatures of 15–35° were obtained in 6 hours and 10–65° in 21 hours with currents of $0.8–0.3^{mm}$ per sec., all being positive, *i. e.*, against the current. After the rheotropic curvature has become considerable a counter curvature due to geotropism appears in *Vicia sativa*, producing a sigmoid form.

By means of decapitation and covering the root tip with collodion caps, Juel sought to determine the receptive region. He concludes that it is the growing zone. Whether or not the tip was also sensitive he could not ascertain. Juel is not yet able to decide what factor acts as a rheotropic stimulus, and plans to make further researches.—C. R. B.

W. C. WORSDELL[10] has done most excellent service in bringing together the chief views in the vexed discussion concerning the nature of the ovular structures in Coniferae. There is probably no more difficult bit of morphology in connection with seed-plants, and the scattered literature of the subject needed organization and compact presentation. The problematical structures are the so-called seminiferous scale and the sporangial envelope. To homologize these structures throughout Coniferae seems to be a well-nigh hopeless task, and a definite solution still remains to be reached.

Mr. Worsdell traces the history of the discussion from Linnaeus (1737) to Celakovsky (1897), although its real beginning on the basis of modern morphology may be said to date from the announcement of gymnospermy by Robert Brown in 1827. The author's judgment favors the conclusions of Celakovsky, who sees in the seminiferous scale the first two leaves of an axillary bud, being developed directly in a highly modified form as an outgrowth on the bract. Furthermore, each of these two leaves represents an outer integument of the sporangium, all of the Coniferous megasporangia

[9] JUEL, H. O.: Untersuchungen über den Rheotropismus der Wurzeln. Jahrb. f. wiss. Bot. **34**: 507–538. 1900.

[10] The structure of the female "flower" in Coniferae, an historical study. Annals of Botany **14**: 39–82. 1900.

having two integuments, the outer being transformed in some cases into the so-called aril. This means that no sporophyll or carpel is present in the group.

This view of the seminiferous scale, which combines the old and separate views that it is an axillary shoot, or a ligular or placental outgrowth, or an outer integument, is certainly ingenious, but has the merit of explaining the well-known varying and transitional abnormalities, the reversed orientation of the bundles, and the diverse structures of such forms as Abies, Cupressus, Podocarpus, Taxus, etc.— J. M. C.

A WIDENING KNOWLEDGE of reproduction in the lower forms has shown that the line between sexual and asexual reproduction is not so sharp as was formerly imagined and suggests that even in higher plants where parthenogenesis does not normally occur it might possibly be induced by artificial means. The only clearly proven case of parthenogenesis in spermatophytes is furnished by Juel in his account of *Antennaria alpina*. Shaw's experiments led him to believe that in *Marsilea Drummondii* parthenogenesis may occur under normal conditions.

Shaw's work has been confirmed by A. Nathanson,[11] who finds that in *M. Drummondii* about 90 per cent. of the megaspores produce parthenogenetic embryos. *M. vestita* was then tried, but the isolated megaspores under otherwise normal conditions produced no embryos. Numerous attempts to induce parthenogenesis by using chemicals were unsuccessful, but by raising the temperature parthenogenetic embryos were obtained. In a lot of 750 isolated megaspores at the temperature of the room only one embryo was found; but in a lot of 466 spores, at a temperature of 35° C., 34 parthenogenetic embryos developed. These embryos when placed in moist soil continued to develop exactly like embryos resulting from fertilized egg cells.

In *M. macra* 101 isolated megaspores at the temperature of the room failed to produce a single embryo, but out of 67 megaspores, at a temperature of 35° C., eight developed parthenogenetic embryos.

The writer satisfied himself that the embryos were truly parthenogenetic and not merely adventitious.— CHARLES J. CHAMBERLAIN.

IN THE *Jour. Roy. Hort. Soc.* (**24**) is printed a paper by H. J. Webber on the work of the United States Department of Agriculture on plant hybridization. The work thus far undertaken has been mainly on oranges, grapes, pineapples, apples, pears, wheat, corn, and cotton. The account is one of progress rather than of practical improvement, and the scientific results are apt to be even more important than the horticultural results. The

[11] Ueber Parthenogenesis bei Marsilea und ihre Abhängigkeit von der Temperatur. Ber. d. deutsch. bot. Gesell. **18**: 99–110. 1900.

work of the hybridization of oranges and other citrous fruits was done in connection with Mr. W. T. Swingle. The aim has been to secure a hardy orange, one with the loose skin of the mandarin, various changes in quality, and resistance to diseases. In the experiments upon pineapple hybridization the problems presented are to secure better shipping kinds, those with smooth leaves, those resistant to disease, and those with larger fruits and of better quality. The main purpose in the experiments on cotton hybridization has been to improve the upland cotton of the interior by means of the fine Sea Island cotton that at present is grown in such a limited area. In experiments on corn hybridization very few of the important problems have been taken up as yet. Something has been done in the direction of the development of the better yielding races. It is in connection with these experiments upon corn that Mr. Webber has developed a remarkable series of results indicating the immediate effect of pollen, a phenomenon known as xenia.— J. M. C.

A SECOND PAPER has appeared on the fertilization of Batrachospermum since my account in 1896. Osterhout [12] agrees with Schmidle that a sperm nucleus passes through the trichogyne into the carpogonium and unites with the female nucleus there, and he figures a stage in the process of fusion. Osterhout also is unable to find a nucleus in the trichogyne. It will be remembered that Schmidle [13] reported that the sperms contained two nuclei, one of which fertilized the carpogonium and the other remained in the sperm or passed into the trichogyne. Osterhout observed only one nucleus in the sperm. If more than one sperm fuses with the trichogyne, their nuclei may enter that structure, but they finally become disorganized. Nuclei that remain in the sperms also break down.

Osterhout's material was fixed after several methods, but that killed in Flemming's strong solution gave the best results. The microtome sections were treated with Flemming's triple stain or with haematoxylin after the method of Heidenhain. The preparations, to judge from the figures, must be much better than any that have yet been made of this plant.— BRADLEY M. DAVIS.

A. C. SEWARD and MISS J. GOWAN [14] have published an extensive paper on *Gingko*. An historical account of the development of knowledge concerning this most interesting plant is followed by a detailed description of its structure, and an account of its fossil allies. The authors approve its separation as a distinct group of gymnosperms, and confirm its cycad

[12] OSTERHOUT: Befruchtung bei Batrachospermum. Flora **87**: 109. 1900.

[13] SCHMIDLE: Einiger über die Befruchtung, Keimung, und Haarinsertion von Batrachospermum. Bot. Zeit. **57**: 125. 1899.

[14] The maidenhair tree (*Gingko biloba* L.). Annals of Botany **14**: 109–154. *pls. 8–10*. 1900.

affinities. Its very ancient character is pointed out, the type possibly merging with the Cordaitales in the Palæozoic. During the Mesozoic and Tertiary Gingko and its allied forms had a remarkable geographical range, representatives having been discovered in almost all parts of the world.

It is of interest to note that the usual statement that Gingko does not occur in the wild state is contradicted, several fine specimens having been found by Mrs. Bishop (Miss Bird) "in the magnificent forests which surround the sources of the Gold river and the smaller Min in western China."—J. M. C.

THE ANATOMY of galls has been recently investigated by Küster.[15a] The paper treats also of the development and morphology of these peculiar structures. Great attention is paid to galls produced by insects, but those which are due to myxomycetes, fungi, algæ, or worms are considered incidentally.

The principal results are the following: the simplest structure is found where the growth of the infected part is superficial, but widespread histological changes occur when there is growth in thickness. Galls which arise through the enlargement of cells already present are very primitive in their anatomical structure.

The epidermis withstands for the longest time the influence of the irritation, the mesophyll, cortex, and pith being more easily affected. The upper side of the leaf seems less liable to change than the lower. The most important change in the epidermis is the formation of hairs. Stomata often remain permanently open, and in some cases genuine lenticels are formed underneath them.

Assimilative tissue is scanty, but mechanical tissue is usually formed when there is any growth in thickness. The vascular system is feebly developed. The larva-chambers are surrounded by mechanical tissue and in shape repeat the form of the galls. In general, the cells of galls have the same form and arrangement as in normal tissues, but forms of cells and tissues appear in the galls which are not found in normal parts of the same plant, though found in nearly related plants. However, many galls show cell and tissue forms which are not to be found in related plants.

Experimental plant physiology has not yet succeeded in producing new organs or new cell formations. Galls furnish the only evidence that a plant through artificial external influences can produce new tissue forms or cell forms.—CHAS. J. CHAMBERLAIN.

DR. R. H. TRUE, continuing his studies upon the toxicity of acids and salts, finds[15b] that, given the degree of ionization of an acid and its sodium

[15a] KÜSTER, ERNST: Beiträge zur Kenntniss der Gallenanatomie. Flora **87**: 117–193. 1900.

[15b] TRUE, R. H.: The toxic action of a series of acids and of their sodium salts on *Lupinus albus*. Am. Jour. Sci. IV. **9**: 183–192. 1900.

salt, the toxic action may be analyzed into the effect of the H ions, the anions, and the undissociated molecules if any. The latter play a particularly important part, especially in the fatty and aromatic series of acids. In general the H ions of inorganic acids are powerfully toxic; the anions of organic acids are slightly toxic, often negligibly so as compared with the H ions; and carboxyl H is many times more toxic than hydroxyl H.— C. R. B.

MR. F. H. KNOWLTON has brought together our knowledge of the fossil plants associated with the lavas of the Cascade range, and has published the result in the Twentieth Annual Report (Part III) of the United States Geological Survey, in connection with an account of the Bohemia mining region of western Oregon. The species number about thirty, including but three ferns and three gymnosperms, and are said to point unmistakably to the Miocene age of the beds.—J. M. C.

PROFESSOR W. A. KELLERMAN, of Ohio State University, and his wife have published an account of the non-indigenous flora of Ohio (University Bulletin, Botanical Series no. 4). In a state known to contain 2025 seed-plants, it seems that 430 of them are not indigenous. These introduced forms are from the following sources: 326 from Europe, 30 from Asia, 2 from Africa, 46 from South and West United States, 21 from Tropical or South America.

PROFESSOR K. MIYAKE, of the imperial University, Tokyo, finds that starch is present in the leaves of evergreens in winter, and that it is due to feeble photosynthesis occurring during that season. The mean temperatures of various days when this process was determined varied from 0.7–7° C. (mostly less than 3°)[16].— C. R. B.

DR. G. N. BEST has revised the North American species of Pseudoleskea.[17] He recognizes seven species, with four varieties, of which three are new. One species, *P. falcicuspis* Kindb., is excluded; and one, *P. atricha* Kindb., is doubtful.— C. R. B.

[16] Bot. Mag., Tokyo, **14**: 44. 1900.

[17] Bull. Torr. Bot. Club **27**: 221–236. *pl.* 6, 7. 1900.

# NEWS.

DR. ROLAND THAXTER sailed for Europe late in June for about two months' absence.

DR. B. M. DAVIS is in charge of the botanical department of the Marine Biological Laboratory at Woods Hole during the summer.

THE *Fern Bulletin* for July publishes a sketch of Daniel Cady Eaton by Professor Setchell, accompanied by an excellent portrait.

DR. B. L. ROBINSON is now in Europe, where he will spend much of the summer examining types of American species in European herbaria.

IN *Rhodora* for June there appears a sketch of Edwin Faxon by Mr. George G. Kennedy, accompanied by an unusually well-executed portrait.

MR. A. C. MOORE, a fellow in botany at the University of Chicago, has been appointed professor of biology in South Carolina College, Columbia, S. C., the state institution.

DR. P. B. KENNEDY, of the Division of Agrostology, U. S. Department of Agriculture, has been appointed associate professor of botany and horticulture in the University of Nevada.

MR. GEORGE P. CLINTON, instructor in botany, University of Illinois, has a leave of absence for the year 1900–1, to study at Harvard. His principal study will be the Ustilagineæ and their allies.

DR. WALTER BUSSE, docent in the University of Berlin, has undertaken a journey through the steppes of German East Africa in search of technically and medicinally valuable plants and plant products.

PROFESSOR GEORGE L. GOODALE sailed in May for Europe. It is his sabbatical year, and he will be away during the coming college year. His work will be done by Dr. R. H. True and Mr. E. W. Olive.

MR. M. L. FERNALD will spend two weeks of July in a botanical exploration of Mt. Katahdin, Me., with J. F. Collins, of Brown University, Judge J. R. Churchill, Dr. G. G. Kennedy, and Émile F. Williams, of Boston.

DR. H. C. COWLES conducted a class in field study of ecology through the Tennessee mountains during June. He has been appointed to take charge of the botanical work at the Biological Laboratory at Cold Spring Harbor during the summer.

MR. C. F. HOTTES, assistant in the botanical department of the University of Illinois, went two years ago to Bonn to equip himself for taking up as a specialty vegetable physiology. His work has proved so satisfactory that he intends staying another year. He will return to the University in September 1901.

A PROSPECTUS of an illustrated work on the maples, native and cultivated, in North America, has been issued by A. M. Lochman, Bethlehem, Pa. The work is to be by Charles L. Lochman, and is to have twenty-four full-page half-tone plates made from photographs of shoots and drawings, with forty-eight pages of text.

PROFESSOR DR. E. LOEW (Berlin, S. W., Grossbeerenstr. 67) and Dr. Otto Appel (Charlottenburg, Schloss-str. 53), who have undertaken to prepare the third volume of Knuth's *Handbuch der Bluthenbiologie*, appeal to all who have made biological observations on extra-European plants to communicate their papers or notes.

MR. B. T. GALLOWAY, chief of the division of vegetable physiology and pathology in the U. S. department of agriculture, was elected a vice-president of the A. A. A. S. and chairman of Section G (botany) for the Denver meeting. Professor A. S. Hitchcock, of the Kansas Agricultural College, was elected secretary of the section.

BACTERIOLOGICAL EXAMINATIONS of the Chicago drainage waters are constantly in progress in the University of Chicago and the University of Illinois. Samples from a score of places along the sanitary canal and the Illinois and Mississippi rivers are examined each week with a view of determining the extent and kind of sewage contamination, and the influence of natural conditions in the purification of the stream.

IT IS EXPECTED that there will be no changes at present in the staff at the Missouri Botanical Garden and the Shaw School of Botany. During the summer Dr. H. von Schrenk will make a study of the diseases of forest trees, in the interest of the United States Department of Agriculture, probably spending most of his time in the Pacific coast region. Mr. H. F. Roberts will pass the summer at the Marine Biological Laboratory at Woods Hole.

THE SECOND ANNUAL SESSION of the Rhode Island Summer School for nature study was held at the Rhode Island College of Agriculture and Mechanic Arts, Kingston, R. I., July 5th to 20th, 1900. In addition to Professor H. L. Merrow of the regular staff of the College and Experiment Station, the following botanists took part: Professor W. W. Bailey and Mr. J. F. Collins, Brown University; Professor J. M. Macfarlane, University of Pennsylvania; and Dr. A. B. Seymour, Harvard University.

THE FOLLOWING NOTE, written in response to our circular letter requesting for review a copy of the book named, may be of interest to botanists who

read reviews of it. They will at least know the price which the publishers offer for "a good review" and the "terms" on which, presumably, the book is advertised by such "scientific magazines" as receive copies:

DEAR SIR: Referring to your memorandum of July 23d, no copies of McIlvaine's *One Thousand American Fungi* have been or will be sent out for review. We have sent a few copies to the editors of scientific magazines, allowing them a special discount of 50 per cent. off the list price in consideration of a good review. Should you care to review the book on these terms we will be glad to send you a copy for $6.

Very truly yours,

THE BOWEN-MERRILL CO.

ON AUGUST FIRST Dr. C. E. Bessey returned to active work in the botanical department of the University of Nebraska. He celebrated his resumption of botanical work by a visit to the Yellowstone Park for the purpose of studying the vegetation of that region, especially certain groups of lower plants. With his return to the department Dr. August Rimbach's connection will shortly cease, as he was engaged in the department during Dr. Bessey's year of service as chancellor. Professor John L. Sheldon, of the Nebraska State Normal School, has accepted a fellowship in botany in the university, and will return to study at the opening of the year. Dr. F. E. Clements, at the close of the Summer School, goes to the Pike's peak region again for further ecological studies of the alpine and sub-alpine vegetation, continuing also his collection of specimens for distribution.

THE PRIVATE HERBARIUM of Mr. Harry N. Patterson, of Oquawka, Ill., containing about 30,000 sheets, has been secured by the Field Columbian Museum, and will be installed with the rapidly growing collections of that institution as promptly as the careful cataloguing practiced in all departments will admit. The botanical department of the museum is to be congratulated upon this accession of one of the notable private herbaria of the country; one that will add a complete collection of Pringle's Mexican plants to its already excellent representation of the flora of that region and the Antillean islands. Mr. Patterson's herbarium is more or less contemporaneous with that of the late Mr. Bebb, which the museum secured some three years ago, and as Mr. Patterson made it his aim to secure a complete series of the species of North America, its addition to the collections of the museum will be of great value to botanical students and specialists in the west.